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1952 - 1953

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A Member shall be an officer or employee of a public or private water works, an engineer, chemist or other person qualified to aid or interested in the advancement of knowledge relative to water works.

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A Corporate Member shall be either a Water Board, Commission, Company or Municipal Corporation.

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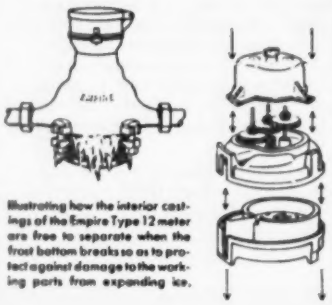

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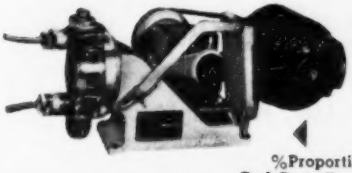

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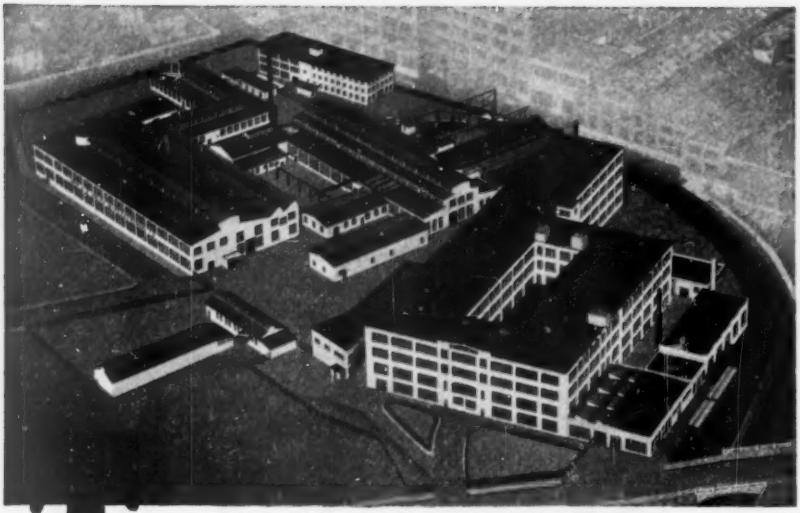

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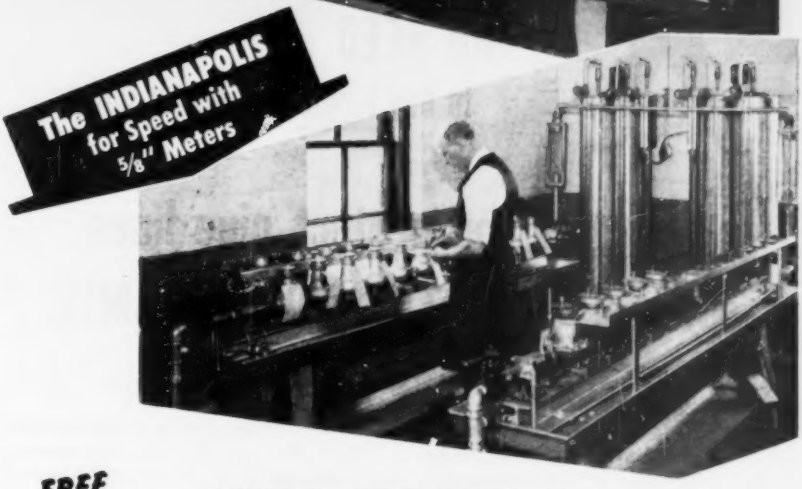

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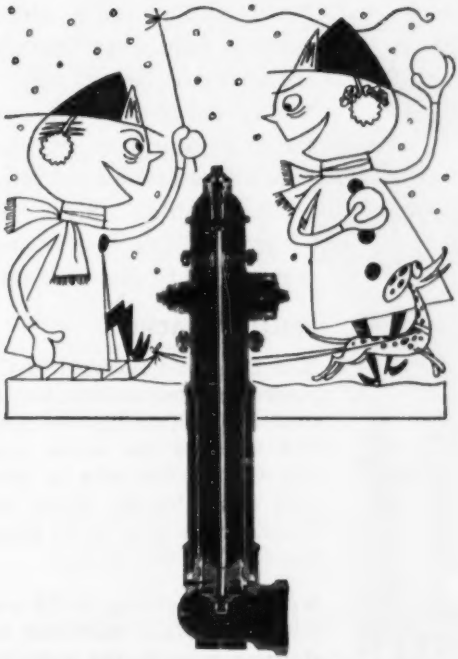

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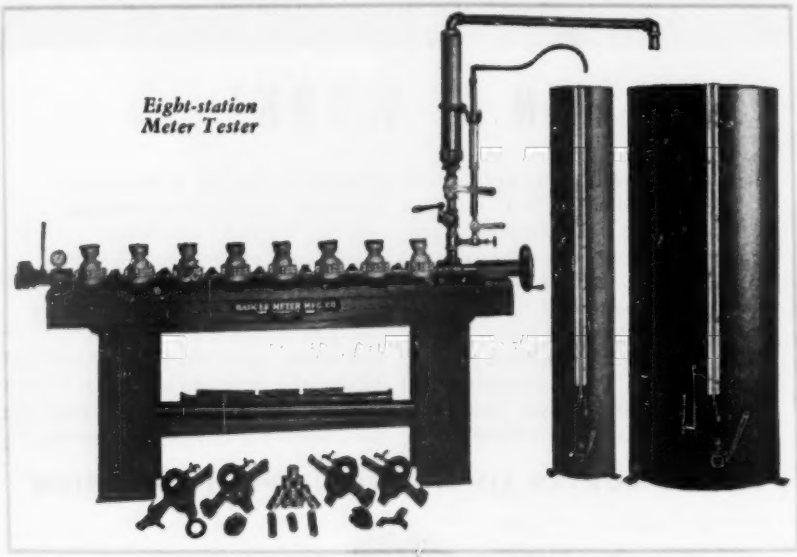

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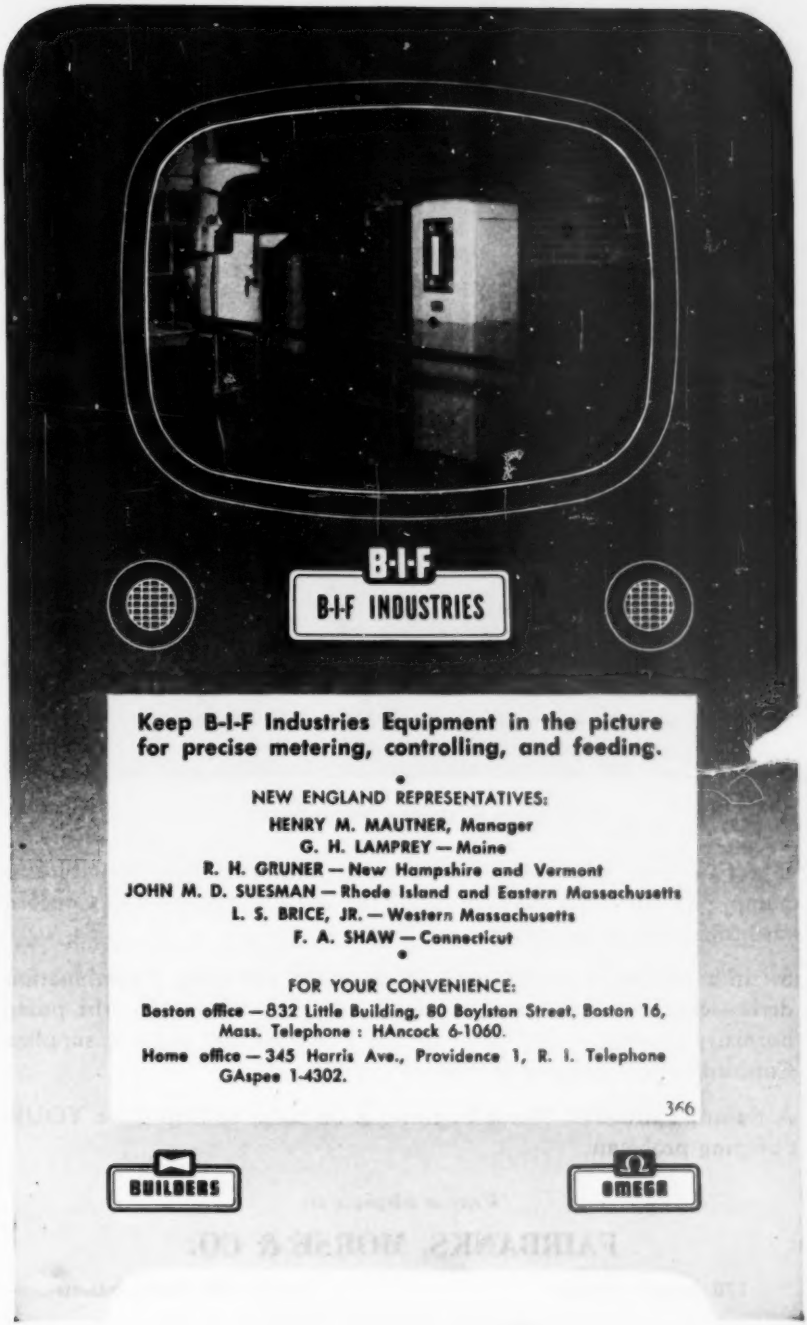

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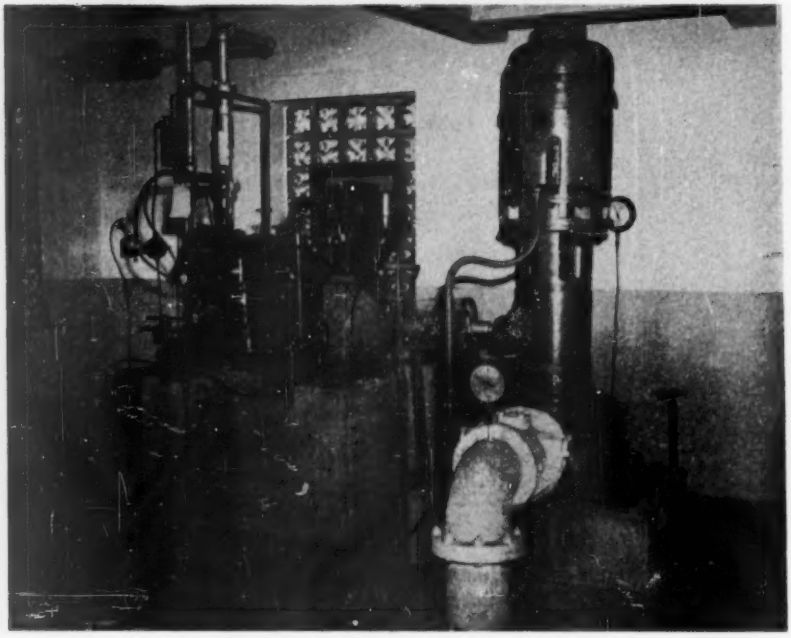

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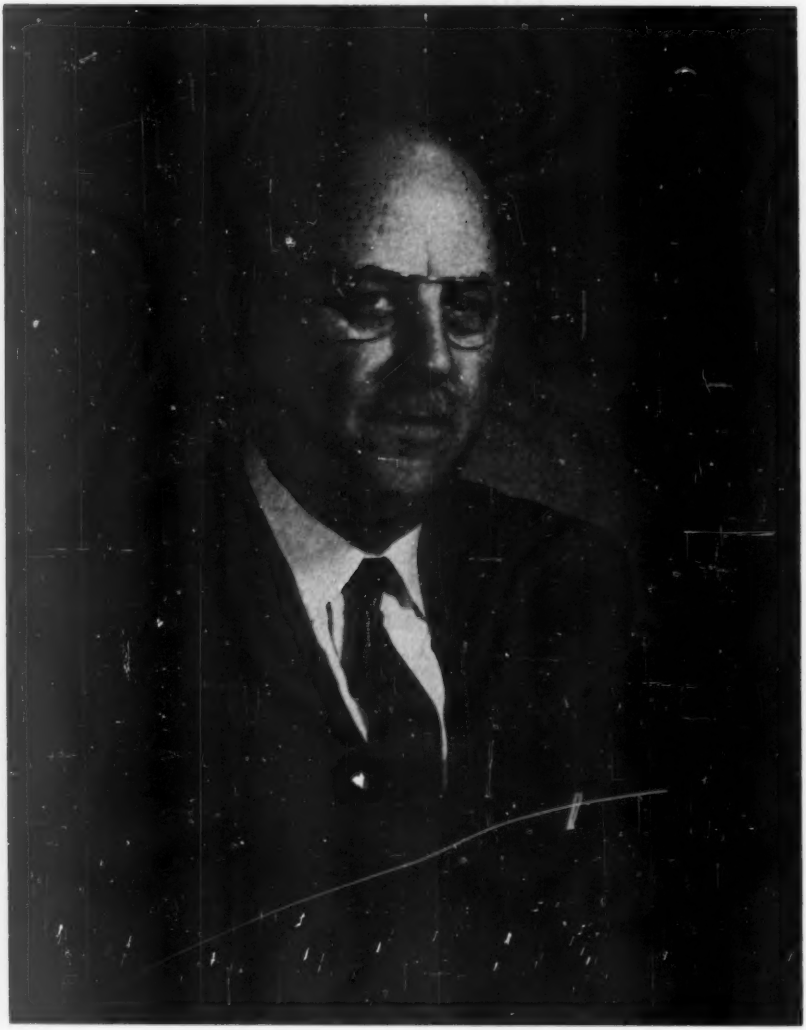

STANLEY M. DORE
President of the New England Water Works Association, 1952-1953

New England Water Works Association
ORGANIZED 1882

VOL. LXVII MARCH, 1953 NO. 1

This Association, as a body, is not responsible for the statements or opinions of any of its members

FORESTRY OPERATIONS ON THE SCITUATE RESERVOIR WATERSHED

BY WILLIAM F. COWEN*

[*Read April 17, 1952.*]

The watershed of the Providence water-supply system is an area of 92.8 sq. mi., located in Providence County, Rhode Island. Of this drainage area, approximately 16,000 acres in the towns of Scituate, Johnston and Foster are owned by the city of Providence, to provide the necessary sanitary control over the reservoir system. As 3,600 acres are devoted to water storage, there remains an area of approximately 12,400 acres for forestry purposes.

The area itself lies within the eastern hardwood region and the forest cover is characterized by a predominance of white, black and red oaks, with a scattering of white ash, red maple and hickory. It would appear that the area originally supported extensive stands of white pine. However, fire, hurricanes and poor cutting practices have practically eliminated the natural pine stands. Almost all of the watershed has been cut over and it is obvious that the hardwood stands will not begin to produce lumber for another 40 years. Since we are confronted with large areas of young stands, both hardwood and softwood, forestry practices will tend toward timber-stand improvement as to species and quality in the hardwood stands, and toward an intensive thinning program and release operations in the pine plantations. The practical yield of this forest area will be pulpwood and cordwood, until the natural hardwood stands and pine plantations have reached a size where profitable saw-timber yields may be anticipated.

The primary problem of forest management will be the building-up of the growing stock in hardwoods and the maintenance of even rate of growth in the pine plantations. As far as soils are concerned, Providence County lies in the glacial region of the northeastern

*Forester, Providence Water Supply Board, 161 Fountain St., Providence, R. I.

United States. The soils have developed under a forest cover, and are largely derived from materials accumulated through glacial action and deposited by receding glaciers as till or by the melting glacier as outwash.

The soils on the reservation can be divided roughly into two classifications:

(1) Soils developed largely from granitic material;

(2) Droughty soils of the kames.

Of the two, the upland soils developed from glacial till are by far the more productive from a forestry standpoint, and excellent hardwood and pine growth is observed on these soils. The soils of the kames present another problem, as these are characterized by a low moisture-holding capacity and high leaching.

It has been found that white-pine plantations on the kame soils are subject to very intensive weevil damage, with the attack reaching 100% of the stand in many cases and rendering the wood largely useless from a saw-timber standpoint. Red pine on the same area will exhibit fairly good growth and present plans calls for open-field planting with red pine.

It is impossible sufficiently to emphasize the fact that tree requirements must be matched with the ability of the soil to supply these requirements. Trees not adapted to the site upon which they are planted will exhibit slow growth and will be subject to extreme disease and insect attack, due to their low vigor. Such mismatching of tree to site will also result in the production of only the lower-grade forest products, such as pulpwood, due to the fact that the stand is characterized by deformed, unhealthy trees, which in most cases will never produce high-grade saw-timber.

Watershed Research

Before describing our forestry and related operations, I should like to cover some aspects of watershed-research management. During the summer of 1951, I was very fortunate in being able to visit the Coweeta Experimental Forest in North Carolina. This forest has natural climatic and physiographic features which are admirably

suited for watershed research. The annual rainfall of 77 in. is well distributed throughout the year, while an average of 100 storms a year allows the collection of an abundance of data in a short time. The 4,000-acre forest is the typical hardwood forest of much of the eastern United States and contains 28, independent, gaged drainage areas.

So far, research has been entirely basic, and has been limited to determining stream-flow characteristics from natural forested watersheds and the influence of forest and forestry practices on water resources. As a forester directly concerned with watershed management, I was very much gratified to find that research in this field has been initiated, and that eventually watershed forests will be managed for the dual purpose of maximum water production and high-grade forest products.

It would seem feasible, especially in mixed hardwood stands, that during thinning operations we might favor those hardwoods which transpire the least water and remove the heavier water users. Before such management can be initiated, research must determine the different transpirational capacities of the various tree species. Another form of treatment might be the outright removal of woody vegetation, growing directly in streams or on adjacent stream banks. It is possible that spraying of such stream vegetation to cause leaf fall might increase water production during times of drought.

The establishment of a strip of conifers on land immediately adjacent to impounding reservoirs has been recommended by various authorities, to reduce hardwood-leaf fall into the reservoirs. In accordance with this recommendation, a 100-foot strip, surrounding the Scituate Reservoir, was planted with various species of pine and spruce. These plantings are now 14 years old, and we are faced with the very practical economic problem of a release cutting, to remove intense hardwood competition, or suffering the loss of 50-60% of these plantings. Due to the severity of the hardwood competition, it probably will be necessary to perform a minimum of two release cuttings at a cost of $20 to $30 per acre, or $240 to $360 per mile. With a 36-mile shore-line, we are confronted with an immediate expenditure of approximately $10,000, in order to perpetuate this 100-ft coniferous strip. I do not doubt that such a strip is valuable, but from a practical standpoint it is a costly procedure by artificial means.

Forestry Operations

When the reservoir was placed in operation in 1925, the problem of the most practical utilization of condemned farm land arose. Rather than wait 60 years for nature to reforest the land, an extensive planting program was initiated. To date, more than 6 million trees have been planted on the reservation. The most extensive plantations are of red and white pine. However, white and Norway spruce, Austrian, Jack and Scotch pine and Douglas fir have all been established. It is interesting to note that these plantations were the first in the State of Rhode Island and have since proven the economic feasibility of establishing such plantations on land which is not suitable for farming or grazing.

The initial 1925 plantings of red and white pine have now reached a stage of development where thinning operations are necessary, if a satisfactory rate of growth is to be maintained. Over the past two years, an intensive thinning program has been initiated, which has resulted in the production of over 2,000 tons of pine pulpwood. Returns from this program are approximately $10.00 per acre.

It has been observed that the 25-year-old pine plantations are carrying between 30 and 40 cords per acre. By removing approximately 8 cords per acre, the stand is being benefited by reduction of light and root competition and the removal of poor-form, low-quality trees. The trees to be removed are marked by the Water Supply Board Forester on the basis of tree form, vigor and spacing. Volume removal is usually limited to no more than 1/3 of the total volume of the stand and, in many cases, it is less than the stated one-third. It probably is better to make a series of light thinnings every 5 years rather than heavy thinnings which would not allow another cutting operation until 10 to 15 years later. The ideal thinning leaves a maximum number of trees per acre which can completely utilize the available supplies of moisture and mineral nutrients.

Thinning methods on the watershed usually fall into two categories:

(1) In alternate-row red- and white-pine plantations, it is usually necessary to remove the white pine almost completely, due to the more rapid growth of the red pine, accompanied by heavy

weeviling of the white pine, which kills the white-pine leaders and allows the red pine to overtop and suppress the white.

(2) In pure stands of red or white pine, tree marking is entirely on the basis of form, vigor and spacing, on a selective basis.

It is interesting to note that the pulpwood contractors prefer to work a selectively marked stand, rather than a row-marking operation. In the latter, the accumulation of slash in the row causes considerable difficulty in the removal of pulpwood by present methods. A selectively marked stand gives more freedom of movement through the stand, rather than containing them between two unbroken rows of trees.

Another interesting point in municipal watershed forestry is the comparison between the use of municipal labor and that of private contractors. Comparative costs were studied on two adjoining plantations, being worked for pulpwood—one operation being handled with municipal labor and the other by a private woods operator. It was found that under the municipal labor plan, it was costing the city of Providence $40.00 per acre, whereas under the "stumpage sale" system to a private operator, the city was realizing a profit of $10.00 per acre. On the basis of this study, pulpwood and cordwood operations are now handled entirely on a stumpage basis. It is apparent that municipal laborers on an hourly basis cannot compete with experienced woods workers, operating on a piece-work basis.

The greatest benefit stemming from the use of private operators in the cutting operations has been that of releasing the city crew for the very important cultural aspects of forestry on a young forest. The city crew now is able to devote its time to release cuttings in young plantations, crop-tree pruning, planting, roadside fire-hazard reduction, and woods road maintenance and improvement.

Release cuttings are often necessary in young plantations. Hardwoods, with their faster initial growth, will overtop and suppress the young conifers, if allowed unrestricted growth. In release operations, those trees which are threatening the conifers are cut at any convenient height and the slash is scattered over the area worked. By the expenditure of $10.00 to $20.00 per acre, it is possible firmly to establish the pine in a dominant growing position, rather than risk overtopping of the pine and loss of the initial expense of planting. In

Rhode Island it is especially important, from a marketing standpoint, that release cuttings be promptly and effectively initiated. Pine pulpwood is readily saleable and will give a return in 20 years, whereas hardwood, due to an almost complete lack of a profitable market, is not easily saleable until it is 40 years of age.

In the natural hardwood stands of the area, forestry management presents a somewhat different problem. Fire, hurricanes and cutting have reduced hardwood stocking to a very low point, and present plans call for very little cutting in these areas, until stand density builds up to an acceptable standard.

Clear-cutting of hardwood is a reasonable practice, wherever pine of sufficient size and stocking occurs as an understory, and on soil that will grow good pine. In most cases hardwood of low quality and vigor is removed, in order to make way for a crop which can better utilize the site and is more valuable economically. Clear-cutting hardwood over pine has provided 150 cords of firewood during 1951-1952.

Marketing

In an area such as Rhode Island, where wood products are not an integral part of the economy, it is extremely difficult to find outlets for wood products. Rhode Island forests have been overcut, blown down and burned, with the result that most of the cover is immature and not capable of yielding saw-timber. Such a condition calls for a market that will absorb a large volume of low-grade forest products. This type of market does not exist, and it is extremely difficult to move wood derived from thinning and improvement cuttings at any sort of profit to the wood owner.

The one market that exists and is capable of absorbing some of this low-grade wood has a virtual monopoly, and is in a position to dictate prices for material by virtue of being the only available outlet for this wood. The condition is definitely undesirable. Prices at the mill are subject to extreme fluctuation, depending on the supply of wood on hand; and in many cases stumpage and piece-work payments have to be recalculated by the time the wood arrives at the mill. At other times, this outlet is shut off completely for a week or more at a time. Since the pulpwood operators gain their living from this market, their livelihood becomes very unstable.

A small market exists for firewood, but again the price is low and, in order to show a profit, it is necessary to cut the hardwood in volume. Any ordinary thinning on a marked-tree basis for firewood would be inoperable, due to two causes:

(1) The operator must remove large quantities to make a profit.
(2) On a watershed forest, the primary consideration is that of maintaining a good cover on the area, which definitely precludes the removal of large volume.

The only way in which this market can be utilized is by clear-cutting inferior hardwoods which are suppressing good young pine. In this way, the stands can be operated at a profit, while good forestry practices are followed. In spite of the drawbacks, we still are very fortunate in having these markets available.

In addition to pulpwood and cordwood, it was deemed advisable to try to develop markets for other products of the land. To date we have established three other markets which, although using small quantities at present, possess the potentialities of absorbing, at a profit, material which otherwise would not be utilized.

The first of these is the product of roadside pine and spruce prunings. Formerly the slash was chipped or burned, in order to effect disposal. At the present time a private operator has been located who uses these branches for Christmas decorations. Although the market exists only at Christmas time, last year 180 bales of evergreen boughs were disposed of, and the future outlook is for an annual production of 500 to 800 bales. No expense is involved for the city, as sales are conducted on a set charge per bale removed.

Another small market, capable of absorbing quantities of otherwise unusable material, is that of witch-hazel brush. Last year 60 tons of this material were removed on a "stumpage sale" basis at a profit. Witch-hazel sprouts very readily and it is anticipated that the areas worked last winter will be available for cutting again in ten years.

The third market is concerned with the swamps which are an integral part of any watershed. In many cases swamps which do not support trees will have a very dense cover of sphagnum moss. This moss is very desirable for nursery work and is also used by florists. The sphagnum moss in the swamps is sold by the swamp, the labor for removal being furnished by the contractor. Several of our swamps

will be operated this spring and, since the harvesting removes only the tops, it is anticipated that they can be worked every five years. Returns from this sphagnum-moss culture will probably not exceed $20.00 per acre.

In conclusion, I should like to state that, even though the marketing situation does not look very encouraging for the near future, good forestry practices will continue to be employed on the Scituate watershed. The majority of our cutting operations have been performed at a profit and we feel that, if a profit can be made in an unfavorable market, the high-grade wood products for which our stands are being managed will be increasingly valuable when better markets become available.

THE OPTIMUM VEHICLE FOR FLUORIDATION—WATER OR MILK?‡

BY J. E. McKEE*

[*Read at Superintendents' Round Table, September 9, 1952.*]

The practice of adding fluorides to municipal water supplies, as a prophylactic measure to minimize dental caries, has gained wide acceptance in recent years. Moreover, it is being urged upon many reluctant water-works authorities by an aroused public. By mid-1951, according to Cox (1), fluoride was being added to 82 supplies, serving a total population of 1,700,000, and approval had been granted for fluoridation of 95 other supplies, to serve nearly 6,000,000 persons. Today, almost every water-works superintendent in the country is faced with the problem of whether to fluoridate or to try to resist the landslide toward this practice.

Advantages of Water Fluoridation

The enthusiasm for fluoridation of public water supplies is not without reason or merit. Already there are scores of papers in the water-works and public-health literature that attest to the fact that the presence of natural fluorides up to 1.0 to 1.5 ppm, or the addition of artificial fluorides to water supplies so as to produce concentrations of 0.8 to 1.2 ppm, is associated with 50 to 60% reductions in the prevalence of dental caries. This effect is shown most dramatically by Dean, Arnold, and Elvove (2), who plotted the incidence of dental caries in permanent teeth of 7,257 children in 21 cities against the fluoride content of the public water supplies. Furthermore, it appears to be well established that the presence of 1.0 ppm of fluoride ion in water is not detrimental to the teeth and bone structure of children or adults; nor does it produce unfavorable reactions or effects in industrial process waters used for soft drinks, brewing, food

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processing, metal plating, chemical industries, etc. Only in the manufacture of ice has fluoride been troublesome and this effect can be overcome by proper control of the process. Thus, the evidence in favor of fluoridation of public water supplies seems to be so positive and so overwhelming that many people cannot understand why it should not be put into effect immediately at all municipal water works.

Objections to Water Fluoridation

There are other sides to the problem, however, and like the arguments in favor of fluoridation those in opposition have a certain logic. Natural resistance arises from the water-works superintendent whose supply originates in numerous wells or surface sources, each of which must be equipped with proportional-feeding fluoridating devices. Scott (3) estimates that the cost of equipment for each source of supply will vary from $1,000 to $15,000. As an example of this problem, consider the water supply of San Bernardino, Cal., which originates in 17 separate well fields and surface streams, all of which are pumped directly into the distribution grid with reservoirs floating on the system throughout the city. The initial cost of fluoridating equipment, appurtenances and housing for this city is estimated at $200,000, not to mention the problems of servicing and maintaining the equipment. Such a cost, to be sure, is a small fraction of the total water-works value and can be readily amortized. On a national basis, the total operating and amortized investment cost of fluoridation has been estimated (4) at 5 to 15¢ per capita per year, but for San Bernardino the annual cost of amortization alone (at 3% interest for 20 years) would be $13,500, or about 20¢ per capita. To this must be added the cost of extra servicing and maintenance as well as chemicals. It is understandable, then, that the complexity and magnitude of such multiple installations cause the public officials to think twice before committing the city to fluoridation.

An argument against fluoridation of public water supplies arises from the fact that only a small proportion of the water is consumed by children, to whom fluoridation will be advantageous. Thus, if a city uses 150 gpd per capita, only about 0.3 gpd will be consumed by the average person, or about 0.2% of the supply. On the assumption that 20% of the population consists of children in the ages dur-

ing which fluoride affects teeth, only about 0.04% (four ten-thousandths) of the added fluoride would be serving a useful purpose. Most of the remainder would be flushed or drained into the sewer, or used for garden watering or car washing.

The third and perhaps most vociferous objection comes from Christian Scientists and other religious groups who balk at "mass medication". The same type of opposition rose several decades ago, when proposals were made to add iodine to water supplies, to counteract tendencies toward goiter; but fortunately this argument abated with the introduction of iodized salt, the use of which is optional. While many public-health-minded citizens may be exasperated by such opposition of minority religious groups, few of them wish to violate the concepts of religious freedom or to incur the ill will of fellow citizens.

Another reason for urging caution in the hasty adoption of water fluoridation arises from the uncertainties and irregularities of water consumption by childen. Maier (5) points out that the degree of caries protection and the severity of fluorosis varies (within limits) with the fluoride intake, and this in turn is dependent upon the amount of fluoridated water consumed, inasmuch as food is a small contributor. Consumption of water, in turn, hinges upon the temperature and relative humidity of the locality, and the season of the year. To determine the optimum rate of fluoridation, it has been suggested that the highest concentration be used that will produce no more than the mildest degree (10% incidence) of dental fluorosis. At Charlotte, N. C., according to Maier, the fluoride level in the water supply is altered from month to month to correlate inversely with water consumption, varying from 1.1 ppm fluoride in January, when consumption is a minimum, to 0.6 ppm in July, when consumption is a maximum.

In his thorough study of food and water requirements of children from one to 12 years old, McClure (6) states: "Drinking of water is a variable factor, especially among children, whose drinking habits are greatly influenced by muscular activity as well as by atmospheric temperature and humidity. It is likewise true of children's diets especially that the requirement of water is met largely by preformed water in the food or by liquid food, particularly milk. The water deficit

made up by drinking water may be a relatively small fraction of the total daily amount of water ingested." That the water consumption varies widely from child to child and, for the same child, from day to day and season to season is evident to all parents. Very few observers of children's habits cite specific data to show the magnitude or the variation of the quantities of water consumed. It is this extreme variation in water consumption that may account, in part, for the dental fluorosis in some children, while others in the same community have numerous caries.

Alternate Vehicles

Granted, then, that the objections to fluoridation of public water supplies have some merit, is there any way that the aforementioned advantages of fluoridation can be achieved without the disadvantages? To answer this question it is necessary to investigate other vehicles, especially pills, dentifrices, chewing gum, salt, solid foods, and milk. The first four of these can be ruled out quickly for obvious reasons. Fluoridated pills and tooth powders, already on the market, reach a very small segment of the population even when highly advertised. Chewing gum is not an aesthetic way nor a reliable means to promote prophylaxis. Fluoridated salt would provide fluorides for adults, to whom it would be of little advantage, but very few children like salt on their foods, nor could careful control over the dosage be exercised. The selection narrows, therefore, to food and milk.

The fluoride contents of meats, fish, hen's egg, cow's milk, citrus fruits, non-citrus fruits, tea, cereals and cereal products, vegetables and tubers, miscellaneous substances, and wine have been tabulated by McClure (7). With the exception of seafoods and tea, the majority of foods found in the average diet contain from 0.2 to 0.3 ppm or less of fluoride in the food as consumed, and consequently the average diet exclusive of drinking water appears to provide 0.2 to 0.3 mg of fluoride daily. Tea was found to contain as high as 398.8 ppm of fluoride in the dry tea, with average values of about 100 ppm, 75% or more of which is extracted by boiling water. At 100 ppm, one tea ball alone would provide approximately 0.2 mg of fluoride. Unfortunately, in this respect, children under 8 years of age seldom drink tea. Nor is seafood generally a favorite of the younger set.

Attempts have been made (7) to increase the fluoride content of vegetables, fruits and grains by adding calcium fluoride to the soil or water in which the plants are grown. The results demonstrate, however, that the fluoride content of the soil or water has little or no influence on the fluoride content of leaves, fruit or roots. Hence, the possibility of increasing the fluoride content of solid foods, other than by the addition of fluoridated salt, appears to be remote. The search narrows further, then, to liquid foods that are acceptable to and preferred by children, or, in other words, to milk.

Milk as a Fluoride Carrier

The fluoride content of cow's milk, with no unusual fluoride in the cow's ration of drinking water, varies from 0.07 to 0.55 ppm, with a median value of 0.10 to 0.20 ppm, according to McClure (7). Furthermore, the addition of fluoride to the cow's ration or drinking water has no appreciable influence on the fluoride content of the cow's milk, the added fluoride probably being excreted in feces, urine and perspiration, as it is for humans (8).

Inasmuch as the natural fluoride content of milk is too low to provide an adequate dietary supplement in the volume normally consumed by children, serious consideration should be given to artificial fluoridation of bottled milk. Such consideration involves questions of assimilation of milk-borne fluoride, quantities and variations of daily consumption, effects of fluoridation on the palatability and nutritive value of milk, universal application, cost, and reception by the public.

Assimilation of Milk-borne Fluorides

To be effective in reducing dental caries, it is apparent that fluorides must be assimilated and must be carried in the blood stream to the tooth buds during the formative period. Mere contact of weakly fluoridated water with exposed enamel of fully formed teeth seems to have little, if any, prophylactic value, although the topical application of a strong 2% solution of sodium fluoride has been effective in reducing dental caries in 7- to 17-year-old children by 40% (10). For these reasons it is desirable that optimum fluoride intake be maintained during the ages from 1 to 10 years and that the fluoride be in a form that can be assimilated.

It appears that natural fluorides in food and milk, or artificial fluorides added thereto, are largely available for assimilation. In fact, McClure (9) showed that when no control was exercised over eating and drinking habits, there were no indications of a difference in total assimilation by young rats of water-borne versus food-borne fluorides.

In other tests, McClure, Mitchell, Hamilton and Kinser (8) added 3.50 to 6.00 mg of fluoride per day in the form of NaF, CaF_2, mineral cryolite, and bone meal to the food or water of five young men, and measured the fluoride eliminated via feces, urine and perspiration. The results showed that about 13 to 55% of the ingested fluoride remained in the feces and hence was not assimilated. Maximum assimilation (80 to 90%) occurred from NaF in food and water, and from CaF_2 in water, while less fluoride was assimilated from cryolite and bone meal. Of the assimilated fluoride, about 50 to 80% appeared in the urine and 20 to 50% in the perspiration, depending upon muscular activity, temperature and humidity. The total daily intake, even at these high rates of ingestion, appeared to have been eliminated practically 100%.

The foregoing tests lead to the assumption that NaF or CaF_2 added to milk would be available for assimilation as readily as the fluorides added to drinking water, and that in concentrations of 1.0 to 1.5 ppm almost all assimilated fluorides would be eliminated from the body rather than accumulate in bones or tissues. It has been demonstrated (16), moreover, that food-borne and water-borne fluorides both have inhibitory effects upon dental caries in rats and both cause mottled enamel when concentrations exceed 1.5 ppm of fluoride.

Quantities and Variations of Milk Consumption

Milk consumption by children is subject to far less variation, by age, sex, season or climate, than is water consumption. Dairies in large cities report that liquid milk consumption is about one pint per capita per day for the entire population and it is estimated that the average child consumes about 1.5 pints per day. Most children from 2 to 8 years of age drink a glass of milk at each meal and possibly a mid-afternoon or mid-morning glass. Moreover, milk consumption

by children does not change much with season, temperature or humidity, for children tend to vary their water consumption instead. The more-uniform consumption of fluoridated milk than of water should tend to reduce the variations in total fluoride intake from child to child and from season to season and thereby should minimize the probability of dental fluorosis in one child while another in the same community has a deficient fluoride intake.

There are some children, to be sure, who do not drink milk, but they are relatively few in number. Deliveries of bottled milk in most metropolitan areas cover wider territories than do the municipal water supplies; in fact, many rural areas throughout the nation are well served with bottled milk. In Los Angeles County there are reported to be over 500 municipal and private water companies supplying domestic consumers, with hundreds more in contiguous areas; yet the Los Angeles telephone directories list less than 70 major milk distributors. To reach a high proportion of children through the few dairies would be infinitely more certain than to try to do it through the numerous water supplies. Similar examples can be cited for many more metropolitan areas, where a few large milk companies reach far beyond the limits of the water-distribution systems.

Palatability and Nutrition

Any detrimental effects of fluorides upon the palatability and nutritive value of milk remain to be demonstrated. Inquiries of local dairy research staffs and biochemists at local universities have failed to uncover any arguments or proof to show that the addition of 0.8 to 1.0 ppm of NaF would alter the taste, nutritive value or enzymes of milk. The writer has been adding 0.5 ppm of fluoride in the form of NaF to the milk used by his family, including three children, and has yet to notice any change in the palatability of the milk or to receive any complaints from the children. This is a matter, however, that deserves more thorough consideration and research.

Cost and Acceptance

The cost of chemicals for the fluoridation of milk, up to 1.0 ppm, is infinitesimal ($0.000,005 per quart) and the dairies should be willing to absorb the cost as part of routine operations. If it becomes

necessary, however, to increase the cost of milk by 1¢ per quart, most parents of small children should be willing to pay the difference, considering the ultimate savings in dental bills. It is assumed, moreover, that the dairies would then advertise and otherwise attempt to promote the sale of fluoridated milk. Thus, we come to the question of acceptance of fluoridated milk by the general public.

It is sometimes surprising how rapidly the public will accept a new idea and clamor for its adoption in local communities, especially after a few newspaper editorials or advertisements or an article in Life, Reader's Digest, or a similar national magazine. That the public should oppose the concept of fluoridated milk, especially when its purchase is optional, seems inconceivable. Dairies could advertise the availability of fluoridated milk for families with small children, pointing out that regular milk is still sold for adults or for those who object to fluoridation. This optional feature should appeal to religious groups who now oppose water fluoridation.

Summary

This presentation of the possible case for milk rather than water as the optimum vehicle for fluoridation is intended not as a firm indorsement thereof, but rather as a stimulant for further thinking and research into the matter. The many arguments in favor of milk as a fluoride carrier are so enticing that some action should be taken by research agencies, either to confirm or to discredit them on the basis of sound fundamental data. The author urges such research and welcomes any logical criticism or reasons in opposition to the ideas propounded in this paper.

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Discussion

Frank E. Law,* D.D.S., M.P.H.—This paper attempts to encourage what M. Starr Nichols described in 1948 as "a forlorn hope that some other means of supplementing the deficient fluoride intake may be found" (1).

"The addition of fluorides to flour, milk, salt or other common articles of diet has been contemplated," Professor Nichols said, "but no method thus far seems so safe, adequate, and economical as the fluoridation of water—safe, because not enough water containing 1 ppm of fluoride could be drunk to cause the least harmful effect; adequate, because every child, regardless of social, educational, or economic status, would be able to benefit without effort on the part of his parents; economical, because it costs only about ten cents per person per year."

Professor McKee, on the other hand, attempts in discussing water fluoridation to revive five arguments used 25 years ago against water chlorination:

1) Feeders cost money.
2) We don't have enough chemical.
3) We don't drink all the water treated.
4) This is mass medication.
5) Individual water consumption varies.

Now, let's explore these objections in some detail.

To begin with, it is true that feeders cost money, but not nearly as much money as McKee believes. In September, 1951, the Wiscon-

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sin State Board of Health published data on the actual cost of installing fluoridation equipment in 29 Wisconsin communities (2). The cost varied from $600 at Soldiers Grove, with a population of 855, to $4,704 at Racine, where the population is 71,464. In towns where there were several sources of water supply, with separate feeder units required at each source, the cost varied from $500 to $1,115 per feeder unit. Usually in such cases only the smallest and least expensive types of feeders were needed at each source. The Wisconsin data are amply supported by other reports on fluoridation costs (3, 4).

In regard to Professor McKee's second point, it is not true that fluoride is scarce.* In fact, there is enough of the chemical now available, at just the present rate of phosphate salt production, to add 1 ppm of fluoride to every water supply in the United States (5).

As for the author's third argument against water fluoridation, it is quite true that we don't drink all the water pumped from our water treatment plants. For many years, however, we have considered it a sound investment to chlorinate all of the 150 gpd per capita pumped by a typical city, in order to prevent contracting one of the enteric diseases from the 0.3 gpd consumed by the average person. We have considered the investment a sound one, even though the thing we are guarding against—pathogenic organisms—may be present in the raw water far less than 20% of the time. Similarly, it is financially sound to fluoridate an entire water supply in order to prevent dental disease, particularly inasmuch as the cost of two dental fillings will pay each individual's share of the cost of fluoridation for an entire lifetime (7).

Along this same line, Professor McKee makes a serious error when he assumes that fluorides affect the teeth of only 20% of the population. It is true that children born and reared on fluoride water until the age of eight or ten do receive the greatest benefits (8). However, children who first begin using fluoridated water at age ten, after their permanent teeth have fully calcified, receive some benefits, too, from fluoridation (9). That the benefits of fluoride water extend into later life is evidenced by the findings of studies conducted among

*_Editor's note:_ In a slight revision of his paper prior to publication, the author eliminated this "second point".

adults who have lived continuously in natural fluoride areas (10, 11). It is reported that at least up to 44 years of age, "the observed caries-inhibitory effect is essentially similar in pattern and in magnitude to that seen in children."

Regarding the familiar argument that fluoridation is "mass medication", if it is wrong to prevent dental disease through fluoridation, then it must also be wrong to prevent the enteric diseases through chlorination. It seems perfectly obvious that, since both fluoridation and chlorination are intended to prevent disease rather than to treat it, neither is a form of mass medication. Fluorides will not cure existing cavities any more than chlorine will cure typhoid fever. Fluoridation's only purpose is to control the concentration of an ion present naturally in countless water supplies at the level proved to be most effective in preventing dental disease.

Although Professor McKee is concerned about the "uncertainties and irregularities of water consumption by children," he agrees that Dean's studies of 7,257 children in 21 cities have proved the efficacy of controlled water fluoridation in preventing dental caries, and he agrees that 1.0 ppm of fluoride is not detrimental to the teeth or bone structure of either children or adults (12). As Dean has pointed out, his findings were obtained "under the conditions prevailing in the localities studied." With such a large number of children and so many cities involved, it is illogical to assume that water consumption was any more fixed or regular than that of children in communities where fluoridation is now being proposed.

In considering possible vehicles for fluoridation of the daily diet, Professor McKee soundly and wisely eliminates pills, tooth paste, chewing gum, and solid foods. Finally, he narrows his search to milk.

Now, I agree it is quite likely that milk-borne fluorides are assimilated just as well as those in water. I cannot concur, however, with McKee's statement that "to be effective in reducing dental caries, it is apparent that fluorides must be assimilated and must be carried in the blood stream to the tooth buds during the formative period. Mere contact of the fluoridated liquid with exposed enamel of the fully formed teeth seems to have little, if any, prophylactic value."

This assumption seems far too broad in view of the evidence, which I have already mentioned, that teeth benefit from fluoride water

beyond the calcification stage, and continuous residents of natural fluoride areas retain a substantial amount of protection against tooth decay until at least the age of 44 (13, 14).

Also, it seems rather naïve to assume, as McKee does, "that the average child consumes about 1.5 pints of milk per day. Most children from two to eight years of age drink a glass of milk at each meal and possibly a mid-afternoon or mid-morning glass."

A four-year study of the food habits of 421 families in Maine disclosed that only 30.4% of the children in four communities were getting 1.5 pints of milk, or more, per day (15). In a study of 2,551 individuals it was found that only 40% of the children received that much (16). And other studies have shown that 1.5 pints is the daily milk consumption rate of only 44% of the white children in Houghton County, Mich.; 24.6% of the negro children in Ferndale, Mich.; 41.2% of the white and 13.3% of the negro children in Alachua County, Florida. Furthermore, "nearly half of the negroes and 22 per cent of the white group in Alachua County drank no milk" (17).

The U. S. Department of Agriculture reports that "calcium is the single nutrient which was most frequently found to be deficient in dietary surveys conducted in United States cities in recent years" (18). Low dietary intake of calcium is always associated with low milk intake, since dairy foods (milk, cheese, and ice cream) supply about 75% of the nation's available food calcium (19).

Professor McKee seems to have spent too much time at the wrong end of the water distribution system. If you follow the pipes into the lower economic areas of a typical city you will find many children who, although they get little or no milk, do drink water every day. If any group can be said to need protection against dental decay more than others, certainly it is the children in low-income families and in large families, whose parents are least likely to be able to pay for dental repairs.

As Nichols has stated in regard to water fluoridation, "every child, regardless of social, educational, or economic status, would be able to benefit without effort on the part of his parents" (20). The record demonstrates clearly that a large percentage of the very children who need this protection the most would not get it through the fluoridation of milk, even though Professor McKee feels that "most

parents of small children should be willing to pay" for any additional expense in fluoridating it.

The American Medical Association and the National Research Council have approved the fluoridation of water. But on the basis of decisions of the former's Council on Food and Nutrition and the latter's Food and Nutrition Board, opposition to the fluoridation of milk could be expected from both of these organizations.

The Council on Foods and Nutrition said in its General Decisions of 1942 that it was "opposed to the indiscriminate fortification of general purpose foods with vitamins or minerals or other dietary essentials." Among the rare exceptions to this general rule, the Council has cited the fortification of milk with Vitamin D.

On December 2, 1944, the Food and Nutrition Board made the following decision: "The Committee on Milk of the Food and Nutrition Board does not, at the present time, favor the general fortification of milk with minerals or with vitamins other than Vitamin D."

Up to the present time neither group has changed its stand on this question.

I am sure you are quite familiar with the history of the study of fluorides, but permit me to review it for you briefly. In 1908 the Colorado Springs Dental Society appointed a committee to attempt to discover why the majority of the children in that city had brown stains on their teeth. They did not find the cause, but they did prove that it was the result of something in the drinking water. In 1916 McKay and Black published the first report on mottled enamel, or "Colorado brown stain," as it was then known.

It was not until 1931 that H. V. Churchill, a chemist, demonstrated by analyses of water samples that excessive fluorides were causing the mottling.

Around 1938 the extensive epidemiological studies of Dean and his associates, which I mentioned earlier, established the inverse relationship between dental decay and the fluoride content of drinking water. Since then, countless laboratory and clinical studies have proved this hypothesis and demonstrated the practicality and safety of controlled fluoridation of public water supplies.

As a result, there are now 416 communities, with a population of about 8,500,000 persons, adding fluorides to their water supplies.

The largest of these is Washington, D. C. (pop. 861,163), and the smallest Norwood Village, Wash., with a population of only 150.

Returning now to the question of milk fluoridation, let me quote from a letter sent to the members of the Conference of State Sanitary Engineers by their Secretary on June 11, 1952:

1) . "It is not known whether the addition of fluorides to milk is effective in preventing tooth decay, although it is known that such addition is effective in water. Further studies of this matter are indicated.

2) "The individual *consumption* of milk by children varies considerably more than their water intake. For economic and other reasons, a considerable number of children in some age groups consume little or no milk. Furthermore, the use of fluorides in milk has not been investigated. On the other hand, we do know, on the basis of examination of many thousands of children who have consumed water varying in fluoride concentration, the amount of fluorides which must be added to water to be effective.

3) "(There is a) possibility that fluoridation of milk may be harmful in an area where the water supply is fluoridated or already contains sufficient fluorides.

4) ". . . practical difficulties and hazards . . . would exist, both in controlling the rate of application and in testing the amount of fluorides added to relatively small volumes of milk by the large numbers of individual milk plants that might adopt this practice. From an administrative standpoint, the fluoridation of milk would spread the responsibility for control, and would necessitate the introduction of a complicated system of supervision.

5) "(There is a) likelihood that only a portion of the milk supply would be fluoridated in a given market, resulting in a lack of uniform distribution. This would reduce the benefits to be obtained by the community as a whole. From this point of view, it would appear that water is a much better vehicle."

In view of these facts, it is difficult to understand why Professor McKee should so strongly favor the fluoridation of milk, when all of the scientific evidence available points to water as the ideal vehicle for this remarkable public health measure.

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GEORGE W. WOOD.* One of the bad features of being a "first" is that you set a precedent and also attain a reputation of being somewhat of an expert. Setting a precedent is all right, provided it does not turn out to be a bad precedent. An expert, to some people, is a person who charges high fees. Since I have never collected high fees, you can see I am no expert. The only claim I may have to any right to appear here is due to the fact that I have been connected with a water company that has been fluoridating its water supply since April, 1951.

We all know, I think, the origin of this fluoridation business, the story of the experimentation carried on, and the present hue and cry on the pros and cons.

Since the word got around that the city of New Britain was fluoridating its water, a large number of requests for information has been received. It has been very interesting to read the newspapers from our neighboring city, Hartford. Some of my friends have collected all manner of articles on the subject for me to read. They are really very entertaining.

The purpose of this discussion is to let you know what has been done in New Britain.

The question as to whether to fluoridate or not was first discussed by the Board of Water Commissioners in September, 1947. The local health officer was consulted, as well as the State Department of Health.

About the middle of 1949 the Board received a letter from the local health officer, stating that he was in favor of fluoridation. Other favorable letters were received from the local dental and medical societies, Dr. Osborn, Commissioner of Health for the State of Connecticut, Dr. Franklin M. Erlenbach, Chief of the Division of Dental Hygiene of the State of Connecticut, and Mr. Warren J. Scott, Director of the Bureau of Sanitary Engineering of the State of Connecticut.

In November, 1949, the Board voted to include in its 1950-51 budget an item for fluoridation. This budget was approved by the Board of Finance and Taxation, the Common Council of the city,

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and the Mayor. There was no opposition. In March, 1950, permission was granted by the Common Council to purchase and install the necessary equipment.

With two sources of supply it was necessary to purchase two dry feeders. Installation was comparatively easy. All surface water is treated at our filtration plant. At this location the chemical-storage room is on the top floor of the head-house. A section of this room was partitioned off to house the equipment. The water supply was connected to the high-pressure water system. The discharge line was run down to the first floor to the control chamber. A ventilating system to take care of the dust was also installed.

The ground-water supply was constructed in 1922. In 1944 a new pumping station was constructed and new equipment installed. This left the old pumping station available for housing the fluoridating equipment.

A Diesel-engine generating station at the filtration plant and one for the ground-water supply provide an available supply of electricity. No additional labor has been required.

Treatment has been continuous since April, 1951. At the beginning a very close check was maintained on the operation. Several tests were made each day at the filtration plant. The State Department of Health made several tests each week. Daily tests were made by the bacteriologist in the laboratory of the City Health Department. Several tests were made on samples taken from various locations in the distribution system.

After two or three months of following this procedure of almost continuous tests, supervision was gradually reduced. At the present time tests are made three times daily at the filtration plant, once each day at the city laboratory and at least once each month by the State Department of Health. About once a month tests are made on samples taken from various points in the distribution system. There is very little deviation from a residual of 1.0 ppm at any point in our distribution system.

We have used sodium fluoride, white, granular, 97-98%. This particular chemical is free-flowing and is practically dustless.

At the filtration plant we have used three different dry feeders, manufactured by the Wallace & Tiernan Co., Inc.,—a Type A-552

chemical feeder, a Type A-635 chemical feeder, and an improved Type A-635 chemical feeder. We also tried several grades of sodium fluoride, as produced by the Chemical Corp. and the American Agricultural Chemical Co. We have endeavored to work with these companies upon a basis of mutual cooperation, in order to arrive at some answers that would be beneficial to the water-works industry.

The original cost of the equipment and installation was slightly under $5,000. The actual cost of sodium fluoride used from April 1, 1951, to March 31, 1952, was $7,364.03. As the water treated during this same period was 3,384 mil gal, the cost was $2.17 per mil gal. Based on the application of a percentage to other purification expenses, such as supervision and engineering, labor, maintenance and amortization of original cost, the costs arrived at were $3.65 per mil gal and $0.15 per capita per year.

At the beginning the men were a little skeptical in regard to handling the chemical, but now they have no fear of it. They have been supplied with respirators and rubber gloves, but seldom use them.

As yet, we have had no complaints, either from individuals or from any type of business.

CLAIR N. SAWYER.* In reviewing the paper by Dr. McKee, I have been impressed by several misleading statements. In addition, the author has failed to offer a discussion of the shortcomings of fluoridation of milk for dental-caries prevention. I feel, as Chairman of the N.E.W.W.A. Committee on Water Quality and Treatment, obliged to make the following statements:

MISLEADING STATEMENTS

1. The author quotes statistics regarding the number of water supplies and milk supplies in San Bernardino, Cal., and Los Angeles County, to show that the installations required to treat water would exceed the number required to add fluorides to milk. This situation is the exception rather than the rule, however, as you may ascertain by consulting the classified telephone directories of a few cities. The small Massachusetts town in which I live, with a population of

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approximately 30,000, is served by 26 different dairies and one water supply.

2. "Fluorides are in short supply."‡ This is an apparent shortage. Additional amounts, estimated to be in excess of the total requirements needed to fluoridate all water supplies, are recoverable from wastes now discharged to rivers by the phosphate-fertilizer industry. This amount has been estimated by Maier at 80,000 tons per year. In addition, fluorides may be recovered from stack gases produced in certain industries and, thereby, we may eliminate an air-pollution problem that exists in some areas at the present time.

3. "Fluoridation of water is a wasteful practice." Yes, it would be if it were necessary to destroy a natural resource to accomplish it. However, silicofluoride has been demonstrated to be as effective as fluoride salts. Silicofluoride is derived from wastes of the phosphate-fertilizer industry. Without recovery, it is continually flowing to the ocean, where it is lost. What is wrong with recovering it, in order to put it to some useful purposes, before it finds its way to the sea?

4. "Christian Scientists and other religious groups are opposed to fluoridation." Many people in these groups are good patrons of the dental profession and, as such, are quick to see that fluoridation of water will reduce their need for dental repair.

5. The author infers that fluorides are of no benefit to adults. There is growing evidence that adults do benefit from fluorides through maintenance of more resistant tooth enamel. Certainly, pregnant women deserve consideration here, as will be pointed out subsequently.

Reasons Why Milk Is Not the Proper Vehicle

1. The proposal to add fluorides to milk is not a new suggestion. The matter has been discussed by nutritionists, biochemists and other groups from time to time. Serious consideration has never been accorded it and there is little reason to believe that the arguments of a few sanitary engineers or chemists will alter matters.

2. *The Cost Item.*—To infer that the cost of fluoridation of milk might be borne by the milk companies certainly does not fit into the pattern set by the companies in regard to homogenization

‡*Editor's note:* In a slight revision of his paper prior to publication, the author eliminated this statement.

and addition of vitamin D. The estimate of 1 cent per quart, suggested as the upper limit, seems very conservative when one considers that milk companies would, undoubtedly, be forced through competition to carry fluoridated and unfluoridated milk in each of the grades which they marketed. This would certainly increase production and marketing costs. Even at 1 cent per quart, the cost per child would approximate $3.00 per year. At such cost, it would seem that topical application programs, conducted through the school systems, would be more reasonable and, possibly, just as effective.

3. *Control of Fluoride Level.*—There is no short, simple method for the determination of fluoride in milk, such as we have for water. This item alone could conceivably drive small dairies out of business, because of their inability to compete with the large companies.

4. *Administration.*—The control of fluoridation, as required by the Food and Drug laws, would be a momentous task. The Boston area serves as a good example. There are 85 producers and milk companies delivering fluid milk in the Metropolitan area. How many more bureaucrats would be needed to keep matters under control?

5. *Personnel Problem.*—Milk-plant personnel is not trained in the science of adding small quantities of chemicals to milk. Many of the smaller plants have practically no laboratory facilities.

6. *Pre-natal Assimilation.*—If the theory that fluorides aid mostly in the calcifying stage is correct, then it is important that the pregnant woman have a source of fluorides during the 7th, 8th and 9th months of pregnancy. Water has many advantages over milk here, as most adults prefer water, tea and coffee.

7. *Post-natal Assimilation.*—It is true that, even today, there are some breast-fed babies. By the time such babies are weaned, all teeth through the six-year molars have calcified or developed to an advanced degree. How will fluoridated milk help these infants? Water is a significant part of the diet of babies in fruit juices and as a thirst quencher.

8. *Legal Aspects.*—The addition of fluorides to a food such as milk would be considered adulteration under our Federal Food, Drug and Cosmetics Act. Adulteration may be allowed in some instances, if it can be shown that the desired results cannot be obtained in any other way in a reasonable manner. It would seem that endorsement

of fluoridation of water supplies by leading public-health, dental and medical groups would eliminate milk from consideration as a possible vehicle. In addition, where adulteration of food products is being considered, the usual test applied is to feed test animals with the food, containing 25 times the proposed concentration of adulterant. If autopsies on the test animals show no deleterious effects, the practice is accepted. Those familiar with the behavior of fluorides know that such a test could not be passed. Fluoridation of water supplies could not pass such tests either. It is only because of the mass of information that has been accumulated on human populations using fluoride-bearing waters that the practice is supported by the leading organizations concerned with the public health.

* * * *

Author's Closing Discussion

In view of the critical nature of the foregoing discussions, the author of the original paper has requested the privilege of presenting a closing discussion in a subsequent issue of this Journal.

WATER MAGIC

BY FRED S. GIBBS*

[*Read September 10, 1952.*]

The title of this paper, "Water Magic", was selected with care and was intended neither to confuse nor to attract members of this Association. The first word, "Water", should be self-explanatory. The second word, "Magic", as well as its use in the title, is explained by Webster: "The art, or body of arts, which claims, or is believed, to be able to procure effects by a mastery of secret forces in nature."

The consulting engineer selects the source of a water supply and designs the distrubution system and treatment plant to insure the continuous production of "water safe for human consumption." The water superintendent dedicates himself to the operation of the works. For twenty-four hours each and every day he is on the job and his greatest concern is to be sure that each tap is receiving "water safe for human consumption." What do we mean by "water safe for human consumption?"

Pathogenic organisms, that are responsible for diseases in humans, must be destroyed to safeguard the health of the community. Turbidity should be removed, because any visible dirt in the water might cause consumers to resort to unsafe waters that are clear. Excessive color should also be removed for the same reason. State public-health standards and U. S. Treasury Department standards for interstate carriers detail the permissible limits of dissolved solids in a satisfactory water from the standpoint of potability.

The water superintendent may be a little shocked to learn that the excellent water produced by his plant—water that has met all tests of purity and standards of potability, and is "safe for human consumption"—would be unfit for many industrial and commercial uses. The complexities of our industrial civilization are such that water which is readily and healthly consumed by humans cannot be used in many processes.

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Some superintendents are familiar with the water-softening requirements of commercial laundries. The calcium and magnesium ions in a water are referred to as "hardness", and water hardness wastes soaps. New England waters are blessed with low hardness, but many laundry operators go to the expense of installing and operating softening units to remove all hardness, *i.e.*, remove all calcium and magnesium ions, so that all soap is utilized in the washing process. In many other parts of the country, where high-hardness waters are common, a commercial laundry just cannot operate unless the city water supply is softened.

The softening of water brings us back to the title of this paper. The "magic" in softening water is in the replacement of the calcium and magnesium ions with sodium ions. In most cases of water softening in New England, the ion exchange is performed by a mineral found in nature—zeolite, a hydrous silicate—or the same mineral artificially produced is used. The hard water—hard because it contains numbers of calcium and magnesium ions—passes through a closed vessel, containing a bed of zeolite. As the water passes through the bed of zeolite, the mineral performs its magic. The sodium ions in the molecular structure of the mineral mysteriously change places with the calcium and magnesium ions in the water. Whereas before contacting the zeolite bed the water contained, for example, a solution of calcium sulfate, after passing through the mineral the calcium sulfate has disappeared and sodium sulfate has taken its place. Presto! Chango! The hard water becomes soft!

The "mysterious" exchange of the calcium ions for the sodium ions is glibly explained by chemists and chemical engineers as "preferential solubility", ion saturation, and several other equally confusing terms, but the Manual of the American Water Works Association, "Water Quality and Treatment", says, "the exact mechanism of the reaction is not definitely understood." I stand on my use of the word "mysterious" and the comparison of ion exchange to the "use of secret forces in nature."

Each pound of zeolite in the bed has a specific number of sodium ions which have the power to exchange places with the calcium and magnesium ions. When the bed's total number of available sodium ions has been exchanged, the zeolite no longer has any effect on the

water passing through. The hard water entering the vessel is just as hard when it leaves. Obviously, something must be done, and again magic is performed.

The incoming water flow is shut off and a saturated brine solution is introduced into the vessel. The brine solution contains ordinary salt in solution, sodium chloride and water. In this solution the sodium is ionized, and when it contacts the zeolite, the exchange reversal takes place. The calcium and magnesium ions in the zeolite exchange places with the sodium ions in the brine solution. When the exchange is completed, the brine solution, now containing calcium chloride and magnesium chloride, as well as some residual sodium chloride, is dumped to the sewer. Presto! Chango! The zeolite is restored to its original chemical composition and more water can be softened.

In New England the softening of water is practically all confined to commercial uses. In other sections of the country the water consumers have demanded and obtained the softening of the entire city water supply. The Metropolitan Water District in Los Angeles operates an ion-exchange softening plant which has a capacity of 200 mil. gal. of water a day.

The softening of water is used as an example of "Water Magic" to illustrate the basic principle involved in ion exchange. In the engineer's quest for purer and purer water, the relatively simple softening of water is greatly overshadowed by today's "Water Magic." The manufacture of plastics has developed synthetic resins that have ion-exchange abilities of many types and uses. While the ion exchange softening of water does not reduce the total amount of dissolved solids in the water, the new synthetic resins can perform the miracle of practically total removal of dissolved solids. The "Parlor Magic" of softening by ion exchange moves to the center of the big stage of demineralization.

The Public Health Service Drinking Water Standards state: "Total solids should not exceed 500 ppm for a water of good chemical quality. However, if such water is not available, a total solids content of 1,000 ppm may be permitted."

Such a water is safe for human consumption, but it would raise havoc in a modern power plant, operating high-pressure boilers. We

recently received a specification covering a power-plant water requirement. This specification shows the vast difference between "water safe for human consumption" and "water safe for a high-pressure turbine." The specification details the maximum permissible content of dissolved solids as follows:

> "The total dissolved impurities shall not exceed 0.5 ppm. Silica as silica oxide shall not exceed 0.03 ppm. Carbon dioxide shall not exceed 0.1 ppm. Iron and aluminum oxide shall not exceed 0.01 ppm."

The Drinking Water Standards permit a total-solids content of 1,000 ppm. or, in other words, the human body can tolerate 8,345 lb. of solids in each mil. gal. of water. The specification states that the high-pressure boilers' water supply shall not contain more than 4.18 lb. of total solids in each mil. gal. of water. Conversely, a human would not care to drink a water of this extreme purity. He would find it flat and tasteless, and the fillings in his teeth would probably fall out, because such a pure water is most active on metals.

It is evident from the specification that this power plant requires a water which is equally as pure as triple-distilled water. The quantities required rule out any consideration of the use of triple distillation, because of its prohibitive cost. The only possible method by which the desired quantities of such an extremely pure water can be obtained economically is through the use of mixed-bed demineralization, the modern magic of ion exchange.

An absolutely pure water would contain only H_2O—two atoms of hydrogen combined with one atom of oxygen in each molecule of the water—with no dissolved compounds in the water. Rain falling from the heavens is not pure water. The earth's atmosphere contains many solids impurities, which become dissolved in the raindrops. The water purity, as required by the power-plant specification, can be obtained by exchanging the positive ions (calcium, magnesium, sodium, etc., called cations) for hydrogen ions, and exchanging the negative ions (bicarbonate, chloride, sulphate, etc., called anions) for hydroxyl ions. The positive hydrogen ions and the negative hydroxyl ions then combine to form—just water.

Water-treatment engineers specializing in ion exchange have developed two methods for accomplishing demineralization. In the first method used commercially, two separate beds of ion-exchange

resins were employed. The water to be treated first passed through a vessel containing a bed of cation-exchange resin. The cation-exchange resin replaced the sodium, calcium, magnesium, and other positive ions with positive hydrogen ions. The water then passed through a second vessel, which contained a bed of anion-exchange resin. The anion-exchange resin replaced the bicarbonate, chloride, sulphate, and other negative ions with negative hydroxyl ions.

In theory, if the cation and anion beds could be of infinite depth, the basic laws of mass action and diminishing returns would be satisfied, and the resultant water produced would contain only hydrogen ions and hydroxyl ions, combined as H_2O. In actual practice, however, the physical limitations in bed depths prevented the completion of the exchange of ions and the effluent water still contained a portion of its original content of dissolved solids.

Quite logically, the next step in ion-exchange engineering was the addition of another cation-exchange bed and another anion-exchange bed, to operate in series with the original two beds. As would be expected, the water quality of the final effluent was considerably improved, *but* the effluent still contained some content of dissolved impurity. In many cases where a higher quality of water purity was required, the engineers would add still another pair of beds, to form a six-bed system.

Then came a major development in the science of ion exchange. By utilizing cation- and anion-exchange resins of different specific gravities, the engineers designed a single mixed-bed exchanger, that was capable of producing water of greatest purity. By mixing the beads of cation and anion resins in one vessel, and considering each bead to be a tiny bed of resin, an infinite number of two-bed systems was formed. The inexorable laws of mass action and diminishing returns were satisfied to a remarkable degree. Water of maximum purity became available for a multitude of industrial and commercial uses.

The regeneration of cation- and anion-exchange resins is accomplished simply with common, relatively inexpensive chemicals, whether the resins are employed in separate beds or in one mixed bed. The anion-exchange resin is regenerated with sodium hydroxide (caustic soda) and the cation resin with sulfuric acid. The amount of re-

generant required is directly proportional to the amount of dissolved impurities to be removed from a water.

A water-works superintendent might think that while the magic of ion exchange is interesting, the performance has never been staged in his town. In that thought he would surely be wrong.

In his town there are probably some amateur or professional photographers who develop their own prints. In photograph developing, the dissolved solids in the municipal water can have disastrous effects on the finished prints. Distilled water, purchased from the local drug store, is relatively expensive and the storage bottle always needs refilling. Furthermore, ordinary distilled water is not pure enough for some photographic requirements. The average photographer today has his own, small, ion-exchange, mixed-bed demineralizing unit that he connects to the city tap. The unit will produce water of a purity far better than that of distilled water, and in generous quantities. When the unit resins are exhausted, they are regenerated easily and simply with acid and caustic.

There are many New England industrial water uses and processes that require water of the utmost purity. Many of these plants receive their water supply from the city, but before the water can be used, it is purified by ion exchange. A listing of products requiring pure water in their manufacture or processing would include:

Beer—The best-quality beers were once dependent for flavor on salts naturally present in water supplies. Now, these special salts are added to water in controlled quantities, after ion exchange removes iron and other objectionable dissolved solids from the water.

Television Viewing Tubes—Impurities in water become deposited on tube surfaces and remain there forever as spots or imperfections, staring back at the television viewer. Demineralized water is a must for producing tubes with a spotless surface.

Ink—Soluble dyes used in ink manufacture are affected by dissolved solids in the process water. Pure water provides full control of the ink-making process.

Whiskey—Gin—Rum—The rectifying of alcoholic beverages requires large quantities of purest water. The high proof of the spirits as distilled is reduced with water dilution. A slight amount of dissolved solids in the water can cause tastes or poor appearance.

Pharmaceutical Products—The color, clarity, purity, and standardization of physiological activity in medicines and drug preparations require the best possible process water.

Candy—Standardization of color, tastes and clarity is adversely affected by dissolved solids in the process water.

The list goes on and on: Condenser Tissue Manufacture; Ceramic Manufacture; Sugar Refining; Soft Drinks; Artificial Ice; Textile Dyeing; Dyestuff Manufacture; Chemicals; Mirror Manufacture; Plating; Cosmetics.

Not all compounds dissolved in water are ionized alike. Some organic compounds—sugar, alcohol, glycerine and gelatine, for example—are present in a water solution as uncharged molecules and are not capable of ion exchange. This fact enables the ion-exchange process to be used for the removal of mineral-compound impurities from solutions of these organic compounds. Ion exchange thus becomes a process application of great importance.

Standardization, production control, quality of product, economy and competition have taught industry the value of ion-exchange processes. The municipality that does not have a few ion-exchange plants within its city limits probably does not have much industry either.

While touching briefly on the use of ion-exchange "magic" on industrial water supplies, mention should be made of other important uses. Ion exchange has been found to be of great value in the removal of toxic substances from certain industrial wastes. Allied with this use, the process recovers valuable metals, such as silver from photographic solutions, copper from rayon wastes, and chromium from spent plating baths. This recovery-of-metals technique developed processes by which ion exchange is used for the recovery of rare earth metals, providing industry with pure metals never before available. If the Atomic Energy Commission would permit, much could be told of the contribution of ion exchange in splitting the atom.

The removal of contaminants has long plagued process engineers Ion exchange, in its infinite flexibility, provides the process engineer with an answer to many problems. In the manufacture of vitamin C, nickel contamination is removed from the sorbitol by a simple passage of the sorbitol through a column of cation resin. Formic acid is re-

moved from formaldehyde by passage through an anion resin. Fruit acid is removed from citrus juice. Hydrochloric and sulfuric acids are removed from lactic acid. The bitter taste in apple juice, malic acid, is likewise removed.

If a water superintendent still thinks that ion-exchange "magic" is not performing in his town, the only reason for his thought probably is that the town is 100% residential and he does not know of any photographers in residence there. But he still can be—and without doubt is—wrong!

Many a good old-fashioned belly-ache has been caused by gastric acidity of inactivation of pepsin. The prevalence of peptic ulcer has not needed an industrialized civilization—only a knife and fork—and there isn't any town in New England without a knife and fork. Ion exchange as a therapeutic agent, in the form of a tiny capsule of purified anion resin, has provided instantaneous relief from pain in countless cases of gastric acidity. The anion resin changes the acid condition into a condition that is bland and harmless. Proved nontoxic and approved by the Federal Drug Administration, ion exchange encourages millions of sufferers. You would not become familiar with ion exchange as a therapeutic through over-the-counter drug-store sales or through national advertising. Only the doctor's prescription —the small slip of paper with the Latin abbreviations and meaningless marks—is the ticket to another performance of ion-exchange legerdermain and, though the performance cannot be seen, it is enjoyed by many!

CORROSION STUDIES

BY JOHN R. BAYLIS*

[*Read September 10, 1952.*]

Considerable time has been given within the past three years to the study of corrosion of cast-iron water mains. The interior and exterior surfaces of a large number of pipes in a few cities have been examined. Much of this was done by examination of the scrap piles of pipe removed from service and "cut-out" pieces on water mains, where a new main of smaller diameter is joined to one of larger diameter already in service. The cut-out generally is made with a tapping machine and often without cutting off the water pressure. As such connections are being made from time to time in all cities, it is not difficult to acquire a large number of the cut-out pieces within a short time.

Changes in the piping are being made from time to time in various sections of the water-distribution systems and occasionally sections of the old pipes are removed. Inspections on the ground have been made at a few places where large pipe lines were being altered.

Examples of Extreme Corrosion

Pipe tuberculation to the extent that the water-carrying capacity has been greatly reduced is so common to water-works employees that it attracts little attention. It too often is regarded as a natural phenomenon, in which nothing can be done to alleviate the corrosion. Although the carrying capacity has been reduced, the pipe still is regarded in good condition. To a large extent it is, but there are extreme cases where corrosion has progressed to the extent that the strength of the pipe wall has been reduced considerably.

Figure 1 shows the inside of a 4-inch cast-iron pipe, over 50 years in service exposed to a soft river water. The pipe was more than two-thirds filled with iron rust for much of its length. The section of the pipe wall in Figure 2 shows that the corrosion has

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FIG. 1.—FOUR-INCH PIPE BADLY CORRODED AFTER 50 YEARS OF SERVICE, EXPOSED TO SOFT RIVER WATER.

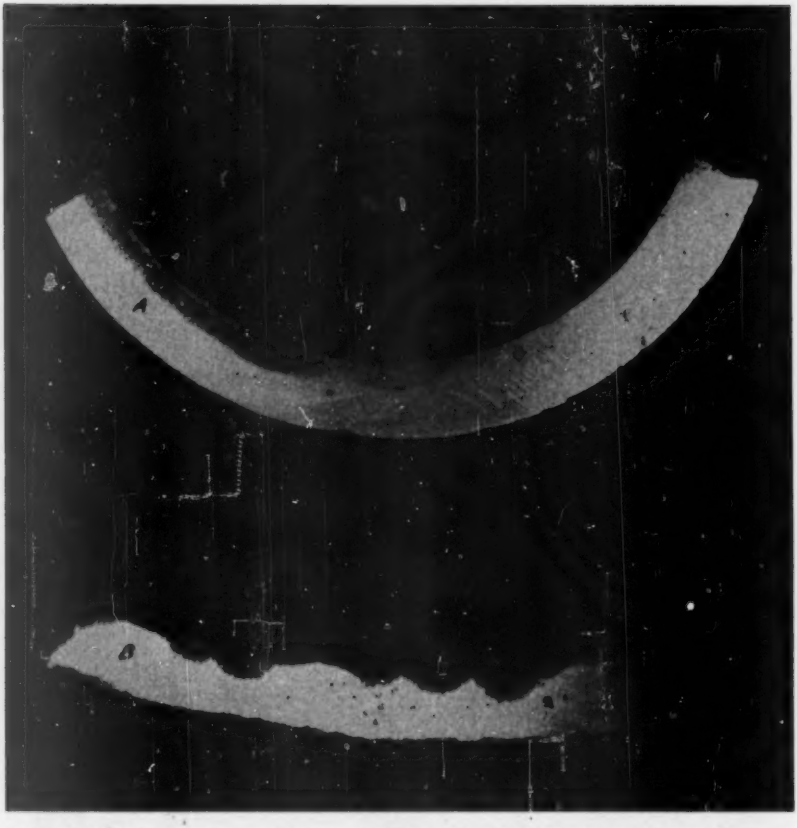

FIG. 2.—SECTIONS THROUGH WALLS OF 4-INCH CAST-IRON PIPE, SHOWING DEPTH OF CORROSION.

eaten nearly one-half through the one-half-inch wall thickness of the pipe over much of the surface. The upper view shows that practically all of the iron has been dissolved in a large area, leaving the slag and other impurities of the cast-iron behind, to make one believe the wall of the pipe has not been damaged seriously. The lower view shows a section where there were tubercles inside the pipe. Under each tubercle there was greater penetration of the corrosion than at other places. This latter condition is characteristic of most cast iron

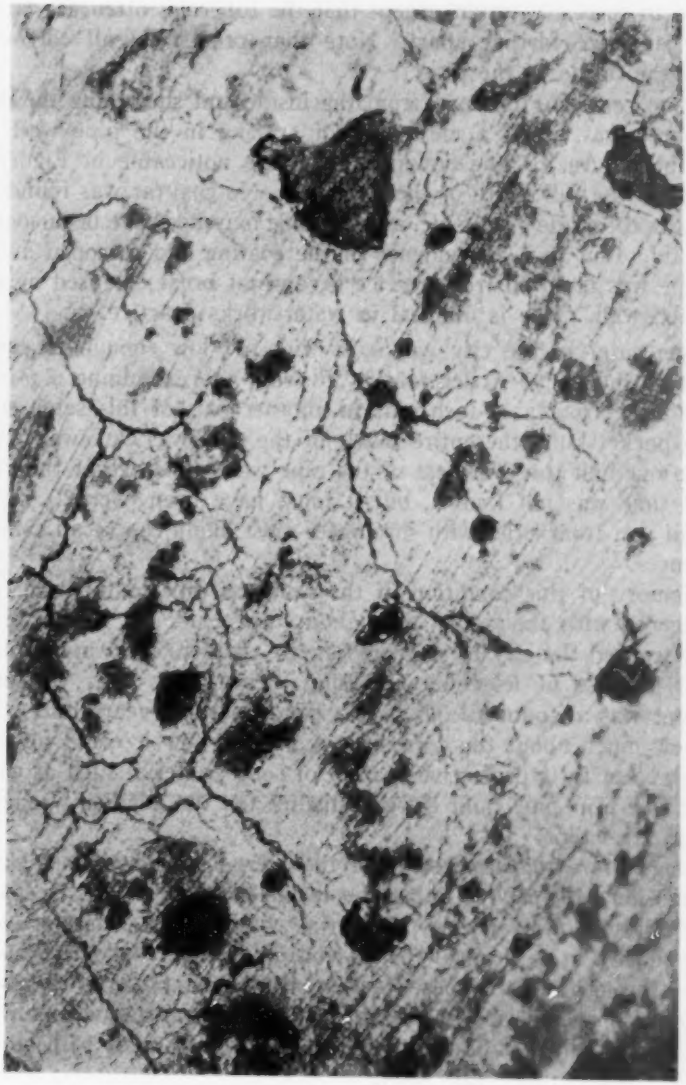

FIG. 3.—CRAZING OF 4-INCH CAST-IRON WATER MAIN, CAUSED BY CORROSION.

exposed to corrosive water, except that the tubercles often are larger in size and are farther apart. Note that practically all corrosion was on the inside of the pipe.

Upon removing the rust from the inside and smoothing the surface, there was found a meshwork of crazing in the pipe wall, as shown in Figure 3. The crazing cracks are noticeable in Figure 2 and extend the full depth of the corrosion. No coal-tar was found on the pipe wall, inside or outside, and the pipe may not have been coated when laid. If it was, all evidence of the coating had corroded away. The pipe was removed from service because of breaks, caused by the weakened wall. This is unusual in water-works practice.

The water in the city was soft, with pH low enough to cause rapid corrosion. The writer recalls 36 years ago examining a 6-inch cut-out piece from a 10-inch pipe in another part of this same city. With a pocket knife the entire inside of the pipe was cut away, one-third to one-half the thickness of the pipe wall. The age of the pipe at that time was not known, but it must have been over 20 years. Many of you from cities with soft water most likely can recall similar experiences.

Memory of this condition of the cast-iron pipe in this one city has lingered with the writer throughout the years. At the time, in 1916, it caused the city to start adding an alkali to the water, solely for the purpose of lessening corrosion. Two years later the lime treatment was abandoned and it was resumed some years later. No one knew much about the corrosion of iron or how it could be prevented, except by a protective coating of some material such as coal-tar for cast-iron pipe, and by galvanizing for the smaller wrought-iron and steel pipe.

Long before this time some of the New England cities tackled the corrosion problem by lining the inside of the pipe with cement mortar. Protection over many years was obtained. Such linings were applied mostly in steel and wrought-iron pipe. Figures 4 and 5 show sections through two of these early cement-lined pipes after about 50 years of service in a New England city. Lining cast-iron pipe with cement mortar did not become common practice in cities with corrosive water until many years later.

The dipped coal-tar coating was the favorite in the early part

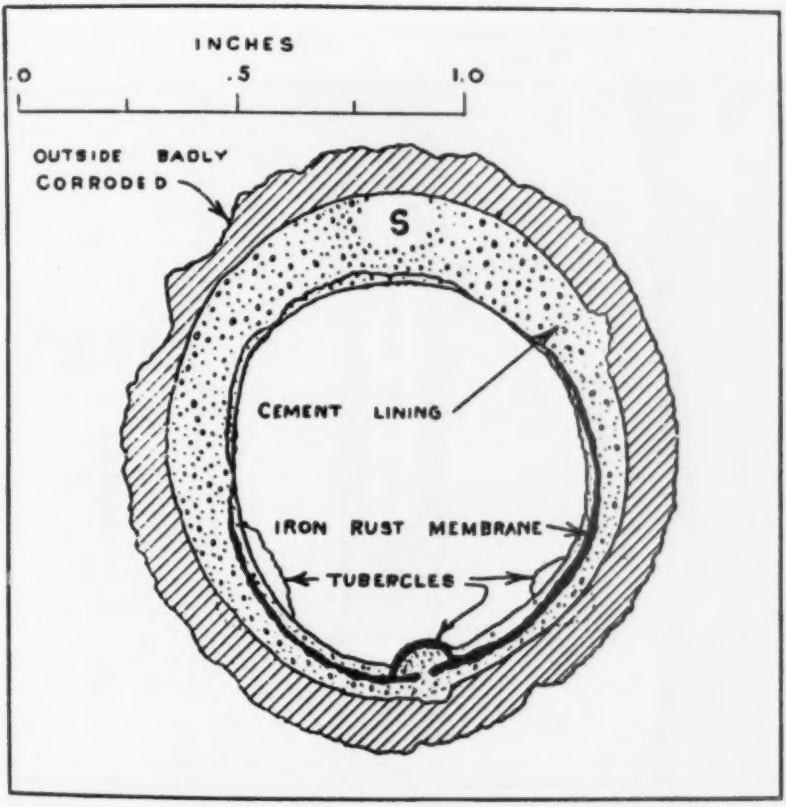

FIG. 4.—ONE-INCH CEMENT-LINED PIPE AFTER 50 YEARS OF SERVICE.

of the twentieth century. There is evidence that some of the coatings were exceptionally good and gave long protection to the pipe.

Figure 6 is an example of another case of excessive corrosion in cast-iron water pipe exposed to river water. The pipe, 40 in. in diameter, had been in service about 35 years, with about 25 years of exposure to corrosive water and about 10 years to non-corrosive water. The pipe wall was a solid mass of dormant tubercles, some of which projected more than two inches into the water. When removed, only an occasional active tubercle was noticed. The writer

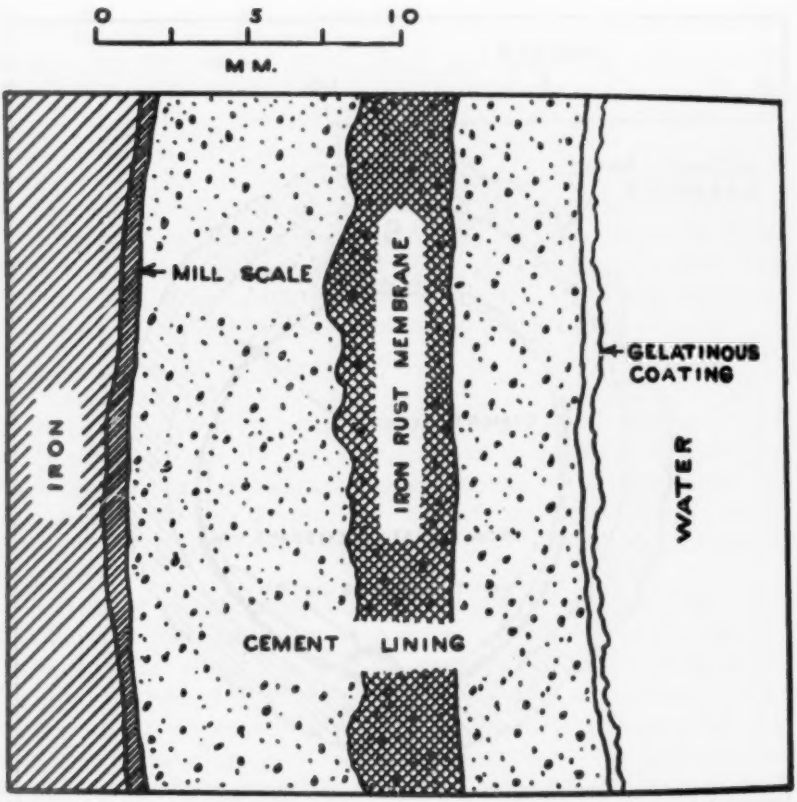

FIG. 5.—SECTION THROUGH WALL OF A 4-INCH CEMENT-LINED PIPE AFTER 50 YEARS OF SERVICE.

has no record of the loss in carrying capacity of the pipe; however, it must have been great. Figure 7 shows a place where a tubercle was removed. A pit extends about ⅝ inch into the pipe wall.

Figure 8 is tuberculation on the inside of a 16-inch pipe, exposed to a moderately corrosive water. Tubercles cover the entire surface of the cut-out piece. One tubercle, 4 in. long, projected more than one inch into the water. Figure 9 is a photograph of tubercles from a piece of pipe removed from service in this same city. These examples of excessive corrosion are given to show what is happening in

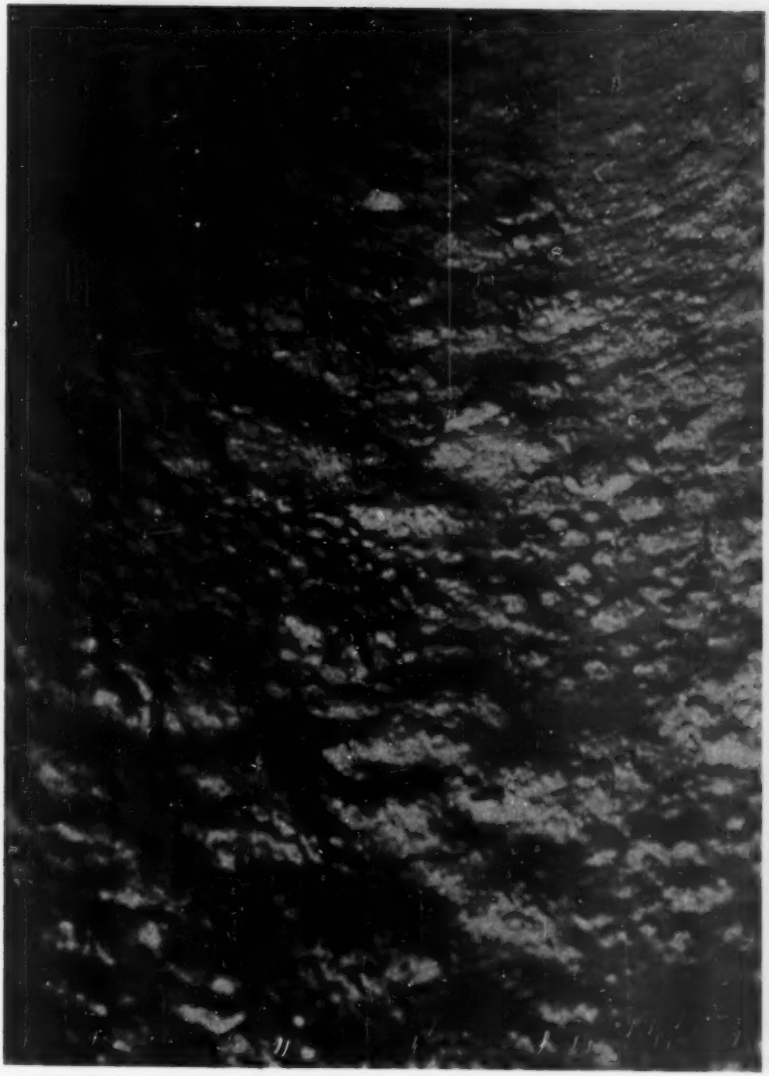

FIG. 6.—EXCESSIVE CORROSION IN LARGE CAST-IRON PIPE AFTER ABOUT 35 YEARS OF SERVICE.

FIG. 7.—ONE TUBERCLE AND SOFT PORTION OF PIT REMOVED.

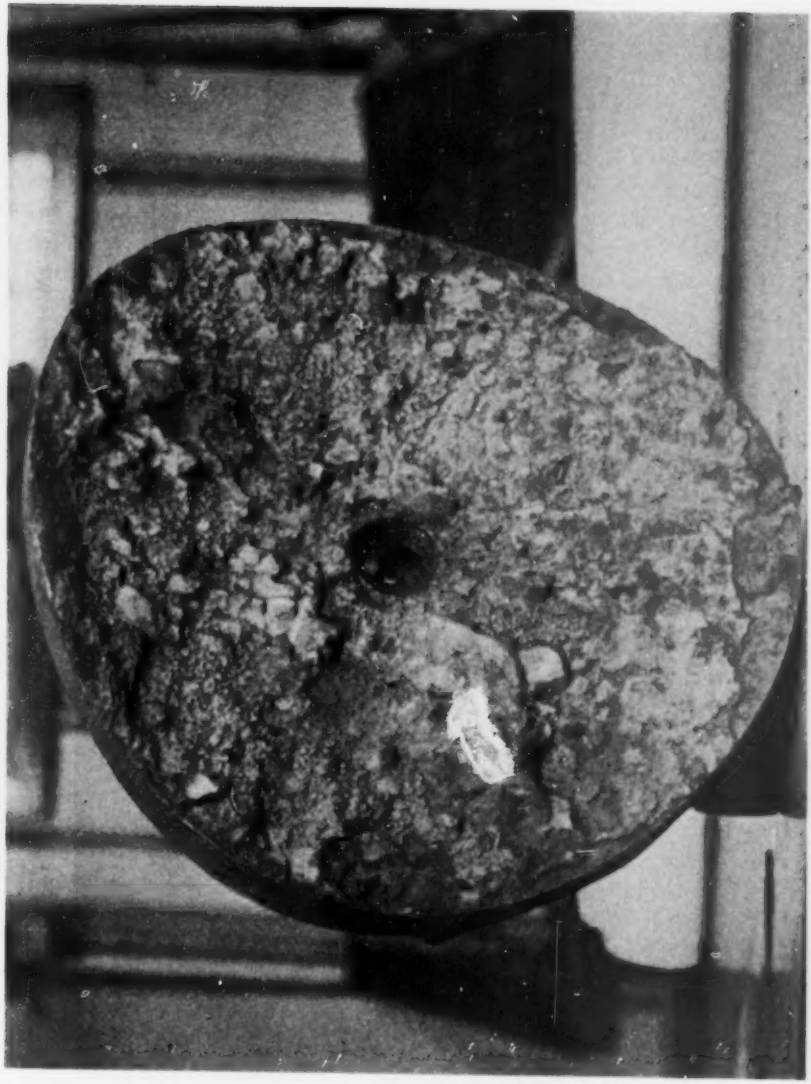

FIG. 8.—TUBERCLES ON 12-INCH CUT-OUT FROM 16-INCH PIPE, EXPOSED TO MODERATELY CORROSIVE WATER.

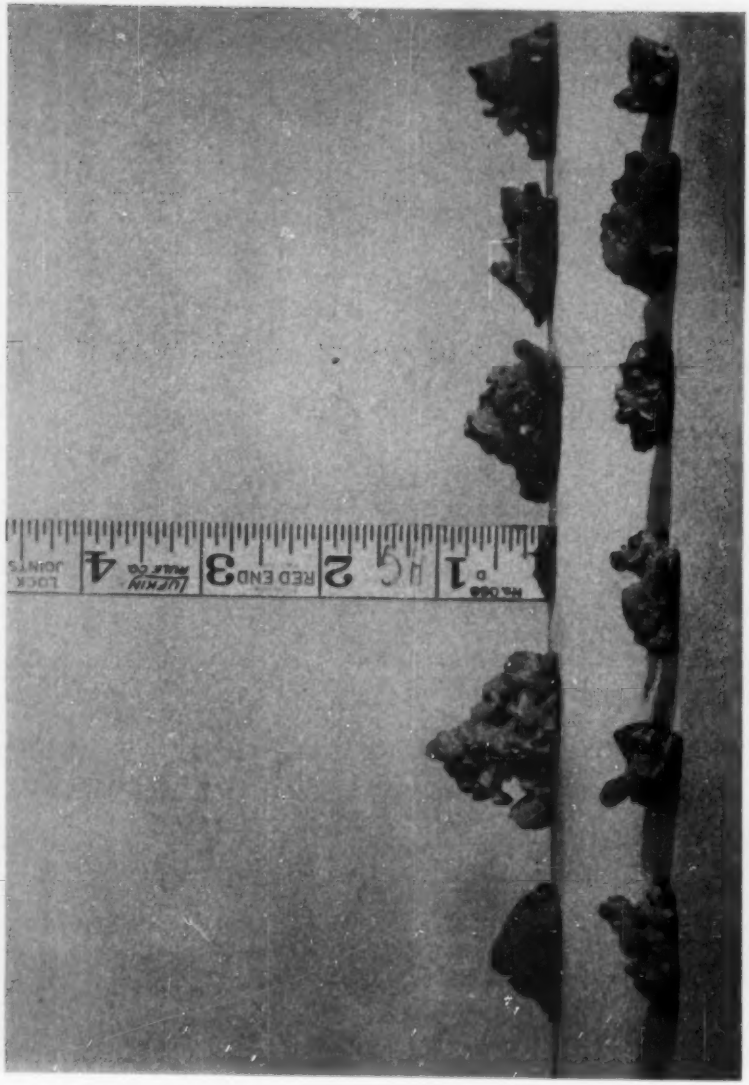

FIG. 9.—TUBERCLES FROM 16-INCH PIPE (NOT LAKE MICHIGAN WATER).

some of the pipes exposed to corrosive and moderately corrosive waters. Almost no calcium remained in the linings.

Non-Corrosive Waters

The writer, in 1922, after several years' study of the causes of corrosion of iron water pipes, came to the conclusion that water just saturated with calcium carbonate, or slightly supersaturated, was the most ideal water for exposure to water piping. He found that no soluble iron above a trace would exist in water saturated with calcium carbonate. Treatment of the Baltimore, Md., water with lime to prevent corrosion was started in 1919. This is believed to be the first public water supply ever treated to the saturation equilibrium of calcium carbonate with lime primarily for preventing corrosion. An article on "The Solution of Corrosion and Coagulation Problems at Montebello Filters, Baltimore" was published in the May, 1922, issue of the Journal of the American Water Works Association. This article attracted almost no attention, and it was not until several years after the publication of "Factors Other than Dissolved Oxygen Influencing the Corrosion of Iron Pipes", in the April, 1926, issue of Industrial and Engineering Chemistry, and "Prevention of Corrosion and Red Water" in the June, 1926, issue of the Journal of the American Water Works Association, that other cities began to give attention to corrosion prevention. Now probably more than 1,000 water-treatment plants use lime primarily to lessen corrosion.

Subsequent to the study of the causes of corrosion from 1919 to 1926, the writer began the search for a water that was naturally just saturated with calcium carbonate, to see if experience over the years confirmed the fact that there would be very little corrosion of the iron pipes. A move to Chicago in 1926 ended the search, for it was found that the Lake Michigan water had the ideal chemical balance to resist corrosion. There was full confirmation of the findings in that the water systems of cities not filtering the lake water were found to be almost free of inside corrosion.

Although the ideal equilibrium for non-corrosive water was found, it has proven difficult to treat some of the waters to the saturation equilibrium of calcium carbonate. The high pH required, particularly where there is magnesium in the water, causes an increase in

soluble aluminum over that present in the water before treatment. This difficulty was encountered in some of the cities in the early trials of the use of lime. When applied in the mixing basin it interfered greatly with the coagulation. In 1920, or the early part of 1921, trial was made of adding the lime to the outlet of the mixing basin in one of the larger filtration plants. Some improvement in coagulation resulted, but not enough to be considered satisfactory. Then the application was shifted to the settled water and soon to the filtered water. It is now being applied at this point in many plants.

Coagulation, followed by filtration, of non-corrosive waters has caused the cities using Great Lakes water for their source of supply to experience more corrosion than cities without such treatment. The calcium-carbonate protective coating that gradually formed in the piping took over protecting the pipe when the coal-tar coating became full of holes. If this coating is dissolved, it allows corrosion to proceed at a rapid rate. Notwithstanding this, the application of treatment to prevent corrosion of the Great Lakes water still is not common practice.

Coal-Tar Coating

We must become aware of the fact that no artificially applied coating will last forever. Most piping used throughout the United States for water mains is coated by the manufacturer with coal-tar, hot dipped. The lengths of pipe generally are dipped into a hot solution of coal-tar. This forms a coating over both inside and outside surfaces of the pipe. This coating has proven very effective in giving protection to cast-iron pipes over a period of years in waters not highly corrosive. In many instances, pipes in service over 50 years in cities using the Great Lakes water have been found to be in good condition. Figure 10 is a photograph of a "cut-out" piece of pipe from the Chicago water system that was in service 70 years with almost no corrosion.

Some of the Coal-Tar Coatings Not So Good

Evidence is accumulating that the coal-tar coating on at least some of the piping manufactured within the past few years is not holding up as well as the lining on some of the older piping. Figure 11

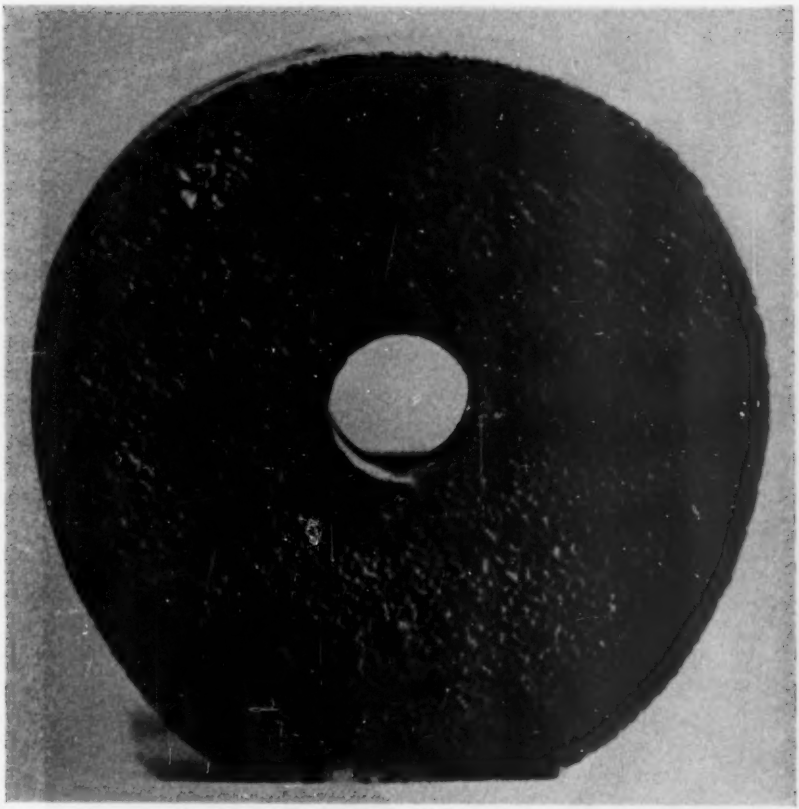

FIG. 10.—SPECIMEN OF WATER-DISTRIBUTION MAIN, INSIDE SURFACE.
8-in. main, Jackson Boulevard, 380 ft. west of Desplaines. Laid in 1880.

shows corrosion of the coal-tar coating on the inside of piping, stored in the pipe yard about one year. Further support of this assumption is the fact that some of the cast-iron pipe and specials used in constructing the South District Filtration Plant at Chicago began to corrode before the piping was laid. After exposure to water, much of it corroded almost immediately.

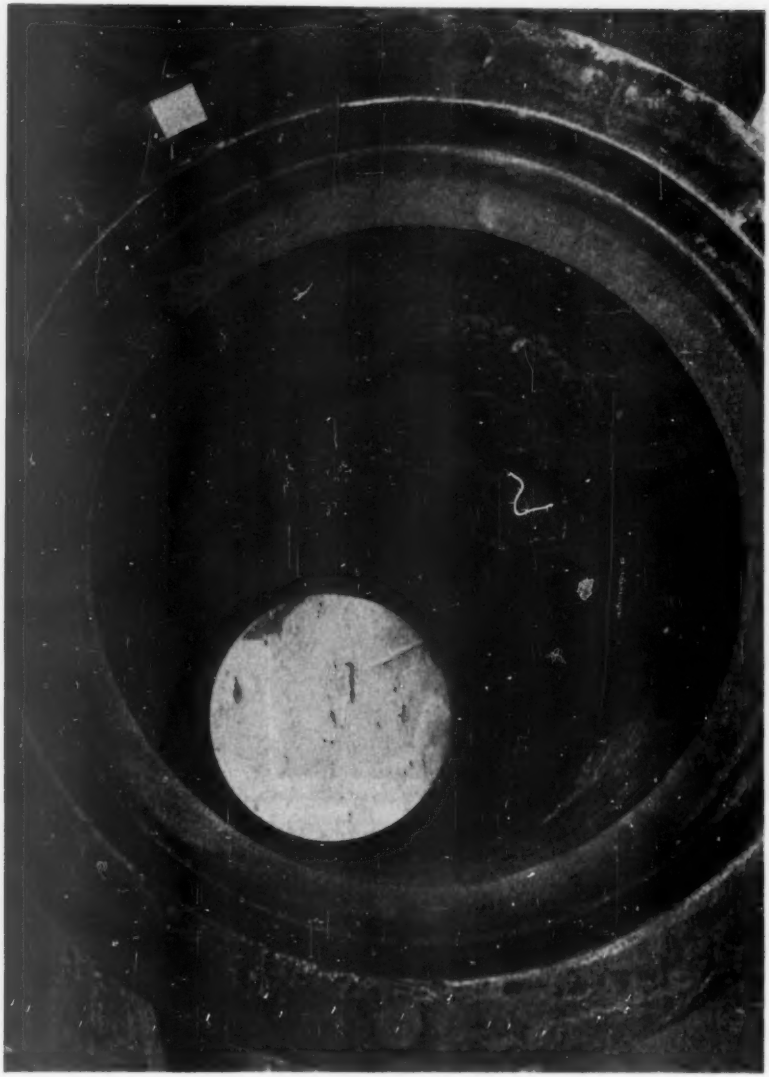

FIG. 11.—CORROSION IN NEW 12-INCH PIPE BEFORE BEING LAID. PIPE HAD BEEN STORED IN YARD ABOUT ONE YEAR.

Corrosion Survey Delayed

During design and construction of the South District Filtration Plant, we had in mind making a survey of corrosion throughout the distribution system of the city, to appraise the condition of the piping, and particularly the cast-iron piping. Details of placing the plant in operation did not allow time to start actively on this survey until about three years ago. Since chemical treatment of the water began in 1945, it was several years afterwards before the corrosion investigation was started.

A progress report was issued in the spring of 1952. This report shows examination of 131 cut-out pieces, in addition to special investigations of piping being removed. Also, conditions in other cities have been examined. About one-fourth of the pieces examined were photographed. Since nearly all of the pipe pieces that showed corrosion were photographed, the photographs would indicate more corrosion than actually exists.

Theory of Corrosion Well Covered in the Technical Literature

According to accepted theories, the corrosion of iron is electrochemical. Since this has received so much attention in the past and is described so extensively in the literature, there is no need to repeat the theory again. To use terms readily understandable to all, iron is slightly soluble in water. Water must be prevented from getting to the iron surface by coatings applied to the iron surface by the manufacturer, or by coatings deposited on the piping from the water. Nearly all small iron water piping is galvanized and, in Chicago, practically all cast-iron pipes used for water mains up to the present time are dipped in hot coal-tar. In years past this method of application has given good covering of the metal surface. No corrosion can take place until holes begin to develop in the coating. The time required for holes to develop may be almost immediately for some of the coatings, and in other instances it may be over 50 years. The tuberculation of coal-tar coated pipe, therefore, may start almost immediately after it is laid or it may be a number of years before starting, depending on the quality of the coating material.

Character of Corrosion Found in Old Water Mains

Two investigations of the condition of piping exposed to Lake Michigan water will be given. These are believed typical of the condition of much of the piping exposed to Great Lakes waters.

Condition of 30-Inch Pipe Exposed to Raw Lake Michigan Water

The 30-inch cast-iron water main is believed to be characteristic of the condition of much of the old piping exposed to the raw Great Lakes water. This pipe line was laid in 1922 and served as a main, connecting two feeder lines. It probably did not have as heavy a flow as some of the feeder mains.

A few lengths of this pipe were removed in 1952, for street improvements. This afforded an opportunity to make a careful inspection of the condition of the piping.

Condition of Coal-Tar Coating

The coal-tar coating on the inside of the pipes was soft and blistered, as shown in Figure 12. Stating that the coating is soft does not mean that the coating is about ready to flow on the pipe surface. Actually it was so disintegrated that it could be rubbed off the pipe with the fingers over much of the surface. The blister coating extended over the inside of each piece of pipe, except for a strip eight to twelve inches wide along the bottom of the pipe, as it lay in the ground. In this bottom strip little of the soft coal-tar remained. Figure 13 reveals little of the blistered material along the bottom of the pipe. The blisters are easily detected between the tubercles on part of the inside surface. The broken line is along the bottom of the pipe.

Tuberculation on Inside of Pipe

On each side of the bottom strip, for a width varying from a few inches to a foot or more, tubercles generally were present in considerable numbers. In some instances the tubercles were more numerous at the top than at the bottom. Generally only a few scattered tubercles were found over the surface of the sides and top of the pipe.

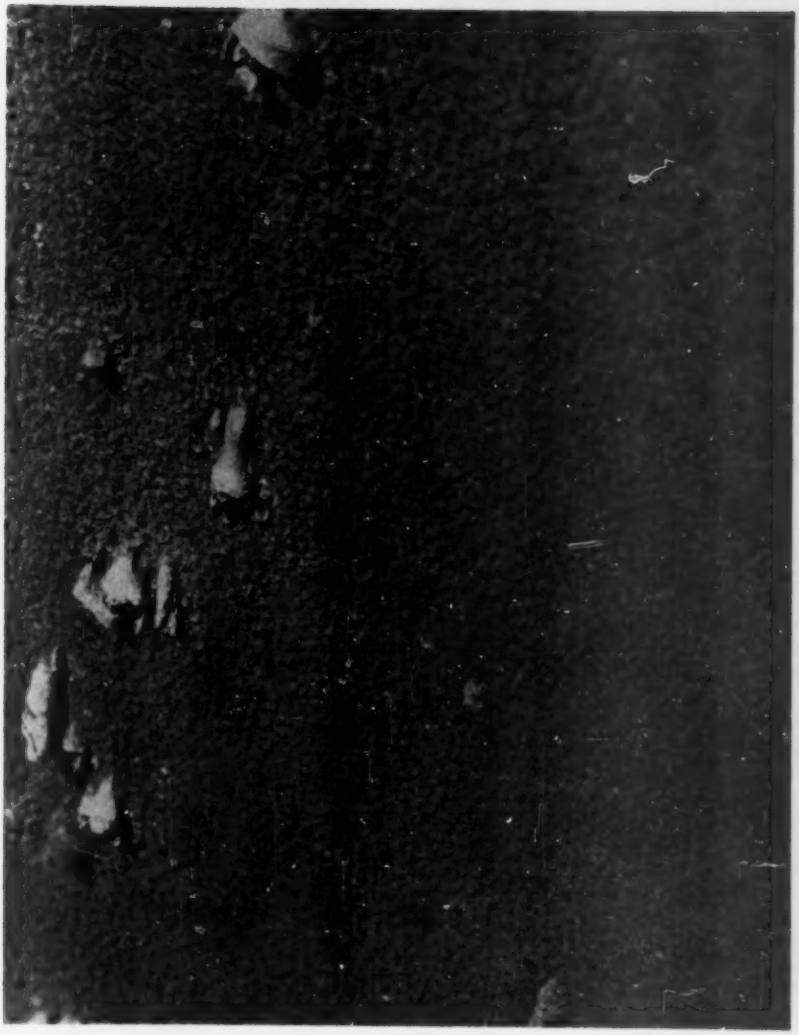

FIG. 12.—BLISTERED COAL-TAR COATING ON INSIDE OF 30-INCH PIPE. A FEW CONE-SHAPED TUBERCLES ARE PRESENT.

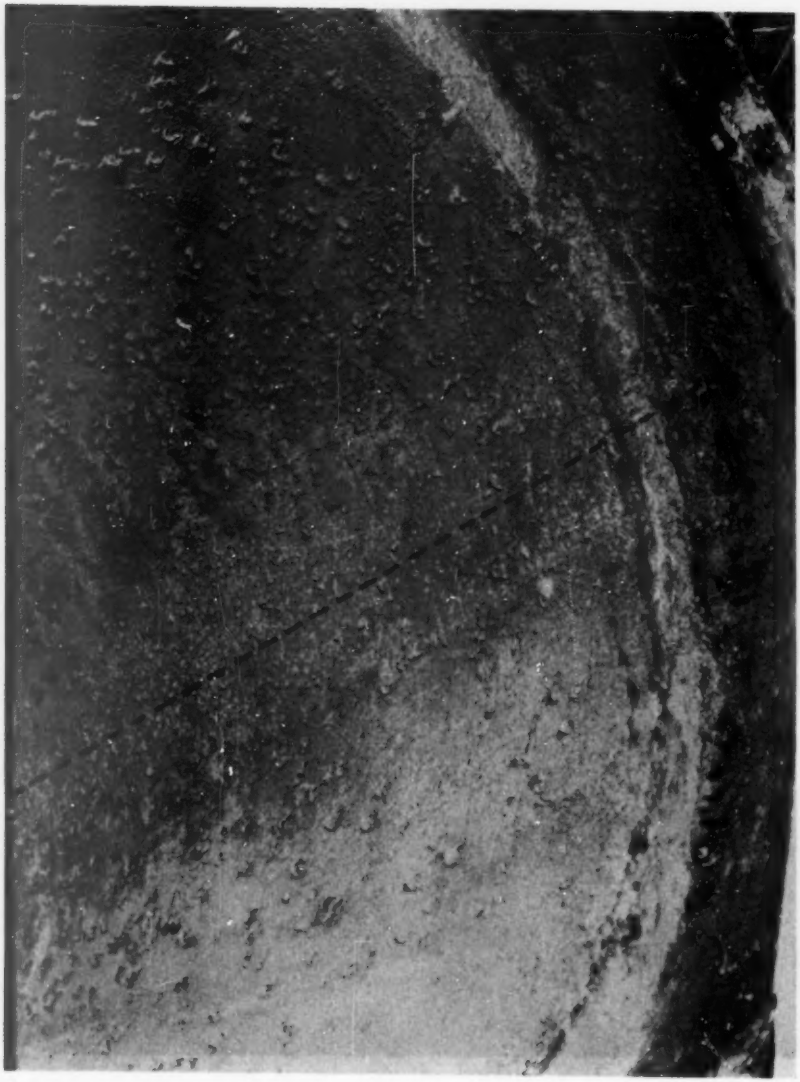

FIG. 13.—BLISTERED COATING AND TUBERCLES ALONG LOWER SIDE OF PIPE.

Tubercles Largely Dormant

Nearly all of the tubercles were dormant, with an occasional active tubercle. The active tubercles were red in appearance and the dormant tubercles were of a dark grey color. It is believed that revival of the corrosion took place in some of the tubercles of this pipe, after it was cut out of service and before being removed from the ground. Tubercles generally are not found in disintegrated coal-tar coatings, such as shown in Figures 12, 13 and 14, and this is an exception to the rule.

Cone-Shaped Tubercles

The shape of the tubercles was largely cuneate or cone-like, as shown more clearly in Figure 14. The tubercles look as though they had formed by growing almost straight out from the pipe surface, and then were pushed over by the flow of water. This, however, was not the case. They formed in the position shown in the photographs. The cone tubercle grows from the small end, which is where it originates. It enlarges in diameter as it grows in length. The pit that extends into the iron underneath the tubercle is at the point of the cone, though there may be some corrosion of the iron along the length of the tubercle, where it adheres to the pipe.

This type of tubercle belongs to the spicule class, in which there is considerable tendency to heal the tubercle with a hard and impervious membrane of magnetic oxide of iron as it grows in length. So long as it is active, the corroding force stays ahead of the healing force. The distance the soluble iron inside has to travel from the point of corrosion keeps increasing and slows up the corrosion rate until eventually the active end of the spicule is closed over with an impervious film. This may not be until a tubercle of moderate size is formed. Water with a considerable tendency to corrode does not form this type of tubercle.

Many of the tubercles inside the pipe were ⅛ inch in diameter at the point of origin, and ⅜ to 3/5 inch in diameter at the downstream end. The tubercles of the larger size varied in length from 1.0 to 1.5 in. None of them were very large or very long. There is belief that the tubercles started to form not so many years ago, after the breakdown of the coal-tar coating, and have grown to the size shown,

FIG. 14.—CONE-SHAPED TUBERCLES AMIDST BLISTERED COAL-TAR COATING.

a few at a time within a short time. As the tubercles became dormant, others started to form by continued disintegration of the coal-tar. Many smaller tubercles were completely healed over, most of which likely became dormant shortly after growth started. This should be expected.

The cone-shaped tubercle is not of common occurrence. Generally, the spicule type of tubercle does not enlarge in diameter, but grows out into the flow of water straight or tilted and does not adhere to the pipe, except at the base or point of origin.

More corrosion existed in these lengths of pipes than generally occurs in the piping system. There is belief that the slow flow in the main was the principal cause of the corrosion. There, of course, had to be a hole through the protective coating on the pipe.

Disintegrated Coal-Tar Coating

The Lake Michigan water, just saturated with calcium carbonate, should be the ideal water to test the life of coal-tar coatings. Any corrosion that starts, when a hole develops through the protective coating, is soon healed with an impervious membrane of iron oxide. The coal-tar remains exposed to the water. The disintegration process of the coal-tar coating, exposed to the raw Lake Michigan water, starts after the pipe has been in service 20 to 50 years, depending on the quality of the material and the thoroughness with which it covers the iron surface. The coal-tar becomes brittle and disintegrates into very small pieces; instead of washing away, it continues to adhere to the pipe surface. Figure 15 is a photograph of a typical blistered surface, enlarged 3½ diameters. Some of the blisters, broken in handling, reveal their hollow structure.

The removal of the coal-tar coating at the bottom of the pipe most likely is aided by suspended objects, scrubbing along the bottom surface. Sand, rust tubercles and other solid material, that may gain access to the pipes where the water is not filtered, gradually scoured the coal-tar away after it began to disintegrate.

Outside Surface

Considerable soil was found adhering to the pipe. The fill around the pipe was largely sand and it is this sand that was adhering to the pipe, an inch or more in thickness in places. The sand was red in

FIG. 15.—BLISTERED COAL-TAR COATING, MAGNIFIED 3½ DIAMETERS.

appearance, due to rust from the corroding iron. The sand was bound together firmly enough still to adhere on some of the lengths of pipes, notwithstanding the handling of the pipes in removing them from the ground and transferring them to the storage yard.

In places, the soil coating could be pealed off by inserting a knife blade between the pipe and the coating. It would break off in pieces a few inches in size. The weakness of the binding between the cemented coating and the iron of the pipe, in places covering a considerable portion of the outside surface of the piping, is a matter of considerable interest. Something unusual has taken place to cause the coal-tar to release its hold on the iron and be removed with the soil coating.

Corrosion in a 6-Inch Pipe

A section of 6-inch pipe was removed to make certain changes in the piping. A section of the pipe about 4 ft in length was delivered to the laboratory for study. This pipe was laid in 1898 and, therefore, had been in service 53 years. Except for the last 6 years of service, it was exposed to the Lake Michigan water without treatment, except chlorination since about 1915.

The section of pipe was cut in two for examination. Figure 16 is a photograph that shows the inside of the pipe. Instead of a blistered coal-tar coating along the bottom of the pipe, there were rust tubercles. The nodules that resemble tubercles in Figure 17 are blisters in the coal-tar coating. These were some of the larger blisters observed on the inside of the cast-iron pipe.

There are several places on the inside of this pipe where the porous material is falling off, but most of it still is present on the pipe surface. The coating is so loose that little is required to knock it off. No rust spots were noted on the upper side of the pipe where the blister coating remains. The porous and disintegrated coal-tar coating apparently still was giving good protection to the iron over most of the inside surface.

Holes in Coal-Tar Coatings

The remarks in regard to holes in coal-tar coatings will be confined to the inside coating of cast-iron pipe. The thin coal-tar coating now extensively applied to such pipes is not likely to be free of holes, even though the iron surface is much smoother on centrifugally cast

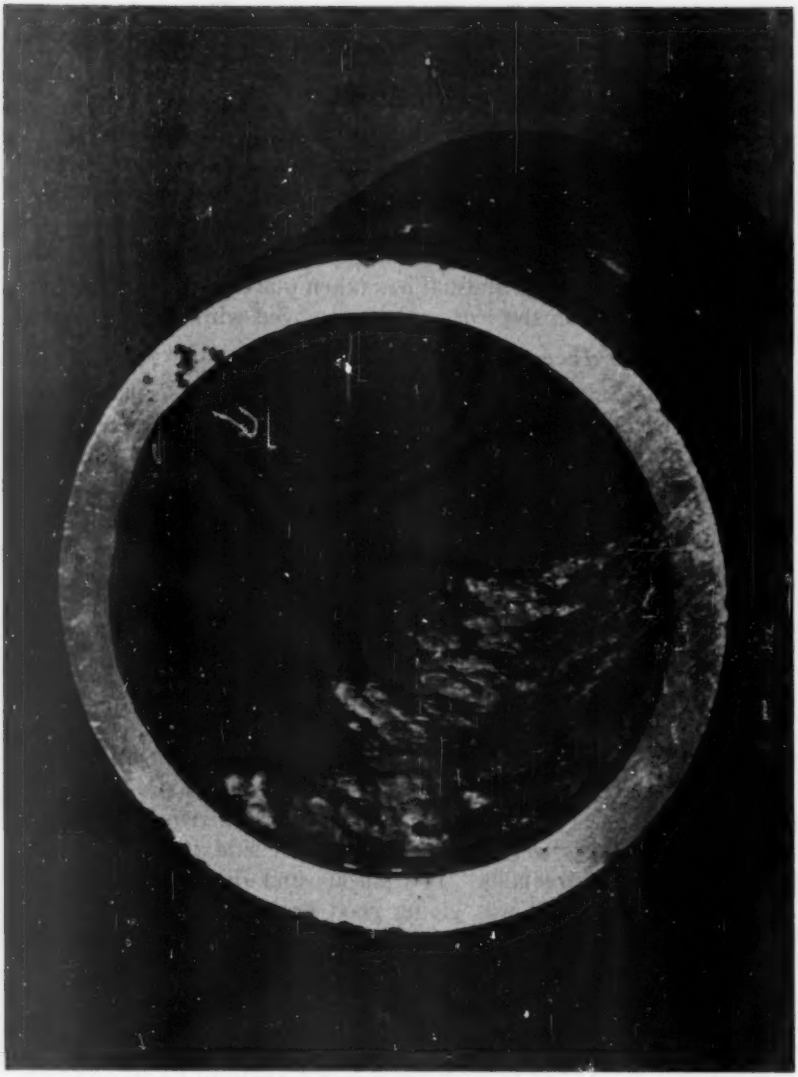

FIG. 16.—TUBERCLES ALONG THE BOTTOM OF 6-INCH CAST-IRON PIPE AFTER 53 YEARS OF SERVICE.

FIG. 17.—BLISTERED COATING IN THE UPPER PART AND SIDES OF 6-INCH CAST-IRON PIPE AFTER 53 YEARS OF SERVICE.

pipe than on the pipe made years ago. Corrosion, therefore, starts in numerous places immediately after exposure to water. Most of the holes through the coal-tar at first are too small to be detected with a microscope, and it is only by submerging in water, so that very small rust spots appear, that the holes can be detected.

Upon examining some pipe which had been in service a number of years, one pipe, exposed to chlorinated Lake Michigan water, showed the presence of 1,000 holes per square inch of pipe wall through the coal-tar, when examined under a low-magnification microscope. Figure 18 is a photomicrograph of the pipe surface. All of the corrosion was stopped by natural reactions before the corrosion spots were large enough to be detected with the eye. Figure 19 is a photomicrograph of the surface of a pipe, exposed to lake water for a number of years and later to filtered water, in which the treatment did not restore calcium-carbonate-solubility equilibrium. The number of rust spots was about the same as for the other pipe, but there was the presence of a much larger number of active corrosion spots. The healing was not rapid and the pipe surface, after exposure to the air, showed reddish color over much of the surface. Within the course of years, given waters of the same characteristics, this pipe most likely will show much more corrosion than that of the pipe exposed to the raw lake water, except for chlorination.

New Coal-Tar-Coated Pipe

The writer is particularly disturbed about coal-tar coatings now being applied by at least some of the pipe manufacturers. Years ago, coal-tar-coated pipe could be stored in yards a number of years without damage to the coal-tar on the inside of the pipe. The few pipe yards visited in various cities recently present a different picture. The coal-tar coating is peeling off after exposure of a few months to two or three years to the air on a considerable portion of the stored pipe. Air exposure may be severe, but surely the manufacturer can do better than this. Most likely some of the manufacturers are doing better.

Removing Tubercles from Corroded Pipe

Those who have had experience in removing rust tubercles from iron pipe realize this is not a permanent restoration of the condition

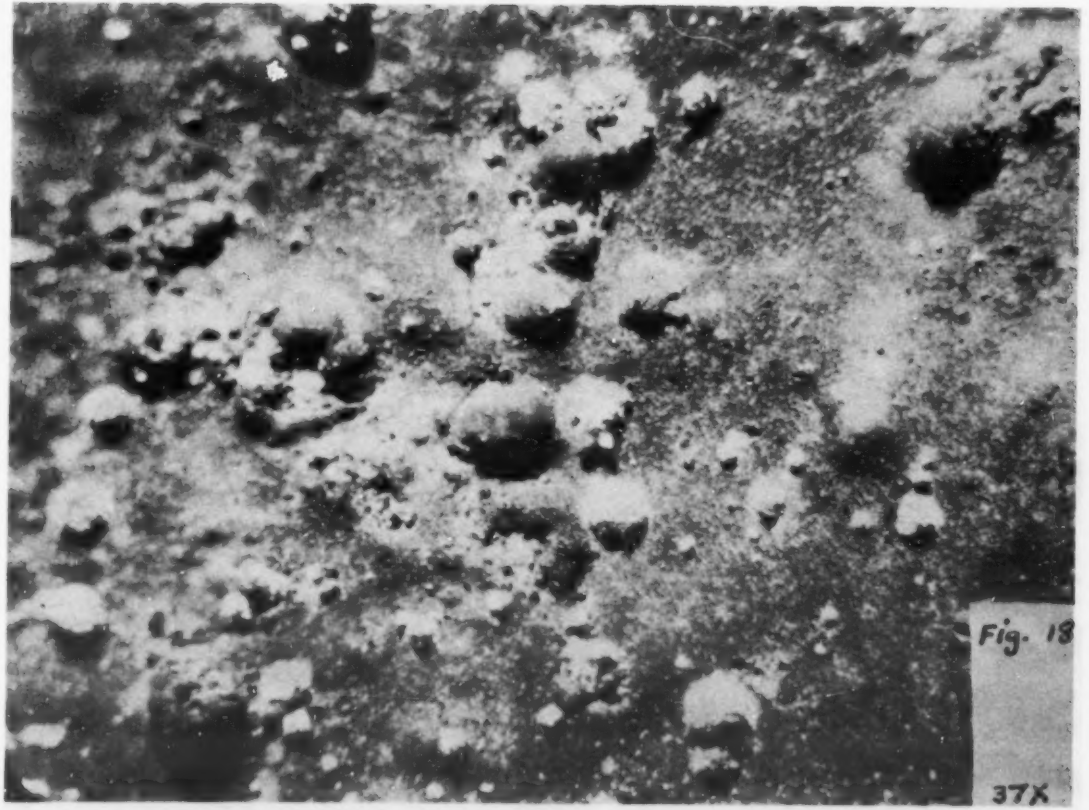

FIG. 18.—PHOTOMICROGRAPH OF PIPE SURFACE, SHOWING BREAKS THROUGH COAL-TAR COATING.

FIG. 19.—PHOTOMICROGRAPH OF PIPE SURFACE SHOWING BREAKS THROUGH COAL-TAR COATING. MANY TUBERCLES WERE ACTIVE.

inside of the pipe line. If a truckload of tubercles is removed in cleaning a water main, within six to twelve months the pipe is ready for more than a truckload of tubercles to be removed at the second cleaning. Each successive cleaning removes more of the protective coating on the pipe surface and increases the tuberculation. The amount of tubercles removed most likely will increase to several truckloads at each cleaning within a few years.

Within the past few years effort has been made to re-coat the pipe surface after cleaning. Thick cement lining may be applied to large-size pipe lines and the result should be good; however, it is not possible to get inside a small pipe. Other methods of coating small pipe have been perfected. The writer has no information on the effectiveness of coatings applied to small water mains. A great need of the water industry is some means of recoating the inside of small pipe.

Crazing

In some instances crazing occurs in the coal-tar coating, as shown in Figures 20 and 21. Rusting often occurs along the lines of the crazing, because holes are opened to the metal surface.

The Everlasting Coating

Calcium carbonate is the only known everlasting coating for iron pipe. The Lake Michigan water without chemical treatment will, within the course of years, form a thin calcium-carbonate coating that will last indefinitely. Figure 22 is a photograph of the inside surface of a pipe, for many years exposed to Lake Michigan water. This coating is so thin that it obviously could not produce much of an increase in friction loss, yet it was giving complete protection to the metal. No coal-tar was found on this piece of pipe. If a coating was applied by the manufacturer, it disappeared years ago. A calcium-carbonate coating can be maintained only when exposed to water that is saturated or slightly supersaturated with calcium carbonate.

Corrosion Is Causing a Great Loss

The value of iron piping, used in conveying water, is an enormous sum. The iron metal, unless attacked by some foreign force, is an indestructible element and will last forever; it does not weaken with

FIG. 20.—PHOTOMICROGRAPH OF CRAZING IN COAL-TAR COATING ON CAST-IRON PIPE.

FIG. 21.—PHOTOMICROGRAPH OF CRAZING IN COAL-TAR COATING ON CAST-IRON PIPE.

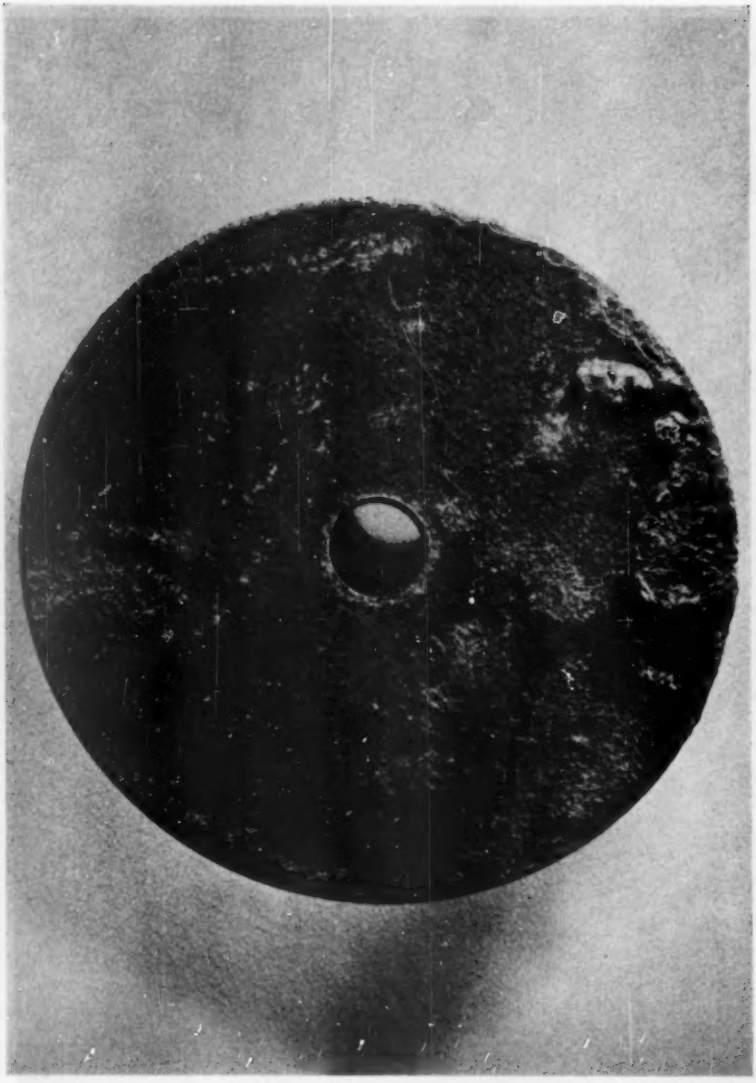

FIG. 22.—CONDITION OF PIPE SURFACE AFTER 70 YEARS OF SERVICE IN CHICAGO WATER SYSTEM.

age. Protected from attack, the iron in the pipes in our homes or the streets of our cities will be just as strong 1,000 years from now as it is today. With full knowledge of these facts, we permit annually many millions of dollars worth of piping to corrode until it no longer is serviceable, or its carrying capacity is so greatly reduced that additional piping has to be installed, to provide the needed carrying capacity of the system.

Protection from corrosion has baffled the scientists from the very beginning of the extensive use of iron piping. The manufacturer has done the very best he knows how in applying protective coatings. The thing we must fully realize is that coatings generally used will not last forever. Not much piping 50 years in service has the original coating on the surface, giving full protection to the iron. All piping now in service will be over this age 50 years from now.

Replacement of small piping in homes alone costs annually many millions of dollars in the cities of the United States. Reduction in carrying capacity of the mains in the streets is costing the water works a considerable sum, in addition to the consumer cost. We should wake up and find means of combating this economic loss.

Cement-Mortar Coatings

The use of Portland cement mortar for lining cast-iron pipe is on the increase, and some of the consulting engineers in the areas where the natural waters generally are corrosive have stated that they are specifying cement-mortar-lined pipe for nearly all of their work. The writer believes the mortar lining is the best coating known at the present time. A word of warning is believed advisable. Such a coating is not going to be free of trouble indefinitely. If the water is such that it dissolves calcium carbonate, the calcium in the cement eventually disappears. After this happens, we do not know if the other ingredients of the cement mortar will remain in place or break loose from the pipe. As long as it remains on the pipe surface, it should give good protection to the pipe. Many years will have to elapse before we can appraise the value of cement-mortar linings. It does give promise of being much more durable than coal-tar coatings.

The water works can do much to prolong the life of cement-

mortar coatings by treating the water to the saturation equilibrium of calcium carbonate. Then the calcium will not be dissolved from the mortar and it should last hundreds of years. Coating the mortar with coal tar or other pipe coating should prolong the life of the mortar, at least to the extent of the life of the coating.

Summary

1. A study has been made of some of the factors which affect the corrosion of cast-iron pipe. This has been limited largely to a study of the life of coal-tar coatings.

2. Unless protected, cast iron will corrode when exposed to most of our natural waters. The extent of the corrosion is influenced by the tendency of the water to form protective films.

3. Waters which readily dissolve calcium carbonate generally are quite corrosive to cast-iron pipe. The effect on the carrying capacity of the pipe often is noticed within a few years after installation of the pipe.

4. Most waters used for public supplies do not corrode to the extent of materially weakening the strength of cast-iron pipe, as is the case with wrought-iron and steel pipe. The chief damage to such piping is the increase in friction loss from tuberculation.

5. Certain waters, such as the Great Lakes waters, are not very corrosive to cast-iron pipe. However, chemical treatment and filtration often greatly increase the corrosiveness of the waters.

6. The coal-tar coating on the piping exposed to the raw Lake Michigan water for periods of 30 to 50 years generally is blistered and of a disintegrated structure, but is giving good protection to the piping. Chemical treatment and filtration cause the disintegrated coal-tar coating to be washed away from the pipe surface and allow corrosion to take place.

7. Tubercles which form in piping exposed to raw Lake Michigan water often are cone-shaped, with the points of the cones pointing upstream. These tubercles become dormant before growing to large size, and these may remain on the pipe surface indefinitely without change.

8. Cast-iron pipe, exposed to Lake Michigan water 70 to 100 years, generally has no coal-tar coating. The pipe surface is coated

with a thin layer of calcium carbonate, that gives excellent protection against corrosion.

9. Chemical treatment and filtration of the Great Lakes water, without restoring it to the original pH, increase its corrosiveness to the extent that the calcium-carbonate coating is dissolved. Rapid corrosion then takes place.

10. Coal-tar coatings, which appear sound to the eye, may contain numerous holes. Some of the holes become the origin of tubercles. Most of the holes become filled with the products of corrosion to such extent that further corrosion is stopped.

11. Crazing of coal-tar coatings occurs occasionally. Cracks which open to the iron surface allow corrosion to take place along the crack.

12. Waters which have a pH at the saturation equilibrium of calcium carbonate, or slightly above, generally prevent the formation of rust in piping coated with coal-tar. Most waters can and should be treated to the extent that the water is saturated with calcium carbonate.

13. Coatings on cast-iron pipe that will last several hundred years are a great need of the industry.

14. Cement-mortar coatings give promise of being much more permanent than coal-tar coatings.

BOOK REVIEW

MAN AND EPIDEMICS. *By C.-E. A. Winslow.* 246 pp. Princeton, N. J.: Princeton University Press, 1952. $4.00.

This volume presents for the general reader an interesting account of the manner in which the science of public health has reached its conclusions and what results have been achieved. The author sketches the research and planning, as well as the medical and engineering practices, which make it possible for the average citizen to take an ample supply of pure water from the tap, to enjoy a sanitary milk supply and to eat at a restaurant without fear of infection. The book also furnishes a historical and philosophical background for the professional public-health worker, although it is not designed primarily for the expert.

The list of chapters is as follows:

1. The Evolution of the Public Health Program.
2. Objectives and Approaches.
3. The Problem of Pure Water.
4. Disposal of Human Wastes.
5. Milk Supply.
6. Sanitary Problems of Food Supply.
7. Insects and the Transmission of Disease.
8. Scourges of the Past.
9. Challenges of the Future.

The author devotes 30 pages to the problem of pure water. In this chapter he discusses the engineering problems of water supply; physical and chemical properties of water supply; epidemics of waterborne disease; purification by storage, by slow sand filtration, by coagulation and rapid sand filtration, and by chemical disinfection; and results of water purification.

The book contains a 5-page list of references and an 8-page index, as well as 17 illustrations.

GEORGE C. HOUSER

PROCEEDINGS

November 1952 Meeting

Hotel Statler, Boston, Mass.

Thursday, November 20, 1952

President Stanley M. Dore in the Chair.

President Dore announced the death of Walter C. Conroy, who had been a member of the Association since June, 1929, and who in the years 1945 and 1946 was Secretary of this Association.

Secretary Knox announced the election of the following to membership in the Association: Charles C. DeFronzo, Superintendent of Public Works, Saugus, Mass.; Virgil Walter Langworthy, Research Chemist, The Chlorine Institute, New York, N. Y.; Edwin A. Schmitt, Head Engineer and Chief, Water Supply Division, Washington Aqueduct System, Washington, D. C.; Edward P. Williams, President, Guilford-Chester Water Co., Clinton, Conn.; Edward J. McDermott, Chief Accountant, Water Bureau, Metropolitan District, Hartford, Conn.; Ralph E. Preble, Jr., Town Engineer and Manager of Water Department, Ipswich, Mass.; Gilbert T. Joly, Assistant Sanitary Engineer, Massachusetts Department of Public Health, Boston, Mass.

Associate: National Supply Engine Corp., Gloucester, Mass.

A talk was given by Edgar F. Copell, Commissioner, Metropolitan District Commission, Boston, Mass., on "Recreational Use of Metropolitan District Commission Reservoirs."

A paper on "History and Problems of the Bangor, Maine, Water Department" was read by Donald P. Johnston, Superintendent, Water Department, Bangor, Me.

A paper on "Rehabilitation of the Exeter, New Hampshire, Water System" was read by Horace L. Clark, Consulting Engineer, Alfred, Me.

December 1952 Meeting

Hotel Statler, Boston, Mass.

Thursday, December 18, 1952

President Stanley M. Dore in the Chair.

Secretary Knox announced the election by the Executive Committee of the following new member: Elmer S. Whiteley, Osterville Water Department, Osterville, Mass.

An illustrated talk was given on "Rain Making" by Dr. Wallace E. Howell, of W. E. Howell Associates, Cambridge, Mass.

A paper on "Hudson River Pumping Station Plant of the Delaware Aqueduct, Board of Water Supply, City of New York," prepared by Torris Eide, Department Engineer, Board of Water Supply, New York, N. Y., was read by Walter J. Gress, Senior Division Engineer, Design Department, Board of Water Supply, New York, N. Y.

AWWA C500-52T
(*Formerly* 7F.1)

American Water Works Association

Tentative

STANDARD SPECIFICATIONS

for

GATE VALVES FOR ORDINARY WATER WORKS SERVICE

These "Specifications for Gate Valves for Ordinary Water Works Service" are based upon the best known experience and are intended for use under normal conditions. They are not designed for unqualified use under all conditions and the advisability of their use for any installation must be subjected to review by the engineer responsible.

Approved by the AWWA Board of Directors as "Tentative" May 9, 1952, to be effective Jan. 1, 1953 (Sec. 17 and 18 effective June 1, 1953)

AMERICAN WATER WORKS ASSOCIATION
Incorporated
521 Fifth Avenue, New York 17, N.Y.

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Notes

AWWA specifications for gate valves were originally adopted June 24, 1913, and modified June 9, 1916. A later revision was approved January 22, 1937, and published as Tentative in the March 1937 JOURNAL. After further revisions, it was adopted as Standard on April 29, 1938, approved by the New England Water Works Assn. on February 16, 1939, and published in the March 1939 JOURNAL. The present version was approved May 9, 1952, effective as a basis for purchase January 1, 1953 (except for Sec. 17 and 18, effective June 1, 1953).

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Tentative Standard Specifications for

Gate Valves for Ordinary Water Works Service

Introduction

These specifications have been developed by an AWWA committee with NEWWA representation. They include, directly or by reference, stipulations concerning materials and are intended to assist purchasers in obtaining gate valves suitable for ordinary water works service. The specifications provide dimensions for bell and flanged ends of valves and include all dimensional information that is essential to uniformity of production.

Section 1—General

Sec. 1.1—Scope

These specifications cover iron-body, bronze-mounted valves intended for ordinary water works service in approximately level setting on buried pipelines in municipal water distribution systems, and include: double-disc gate valves with nonrising stems (Fig. 1), having either parallel or inclined seats, and solid-wedge gate valves with nonrising stems (Fig. 2).

Sec. 1.2—Valve Pressure Ratings

Valves shall be designed for operation at working water pressures not exceeding 175 psi for valve diameters of 3 to 12 in., inclusive, and 150 psi for valves from 16 to 48 in., inclusive. Operating pressures or sizes of valves which fall outside these limits are beyond the intended scope of these specifications and require special consideration in design and construction.

Sec. 1.3—Conditions Not Covered

These specifications are not intended to cover special conditions of installation or operation—such as built-in power drive; installation in vertical or steeply inclined lines; conveyance of water of unusual corrosivity (pH less than 5); excessive water hammer; frequent operation, as in filter service; or operation in throttled position. Such conditions are beyond the intended scope of these specifications and require special consideration in matters of design and construction.

Sec. 1.4—Information to Be Supplied by Purchaser; Supplementary Specifications

1.4.1. In placing orders for valves to be manufactured in accordance with these specifications, purchasers should specify the following details:

1.4.2. Specification used—that is, AWWA C500.

1.4.3. Size of valve.

1.4.4. Quantity required.

1.4.5. Type of valve as specified under Sec. 1.1.

1.4.6. Whether records of tests are to be furnished as specified under Sec. 2.2.

1.4.7. Type of valve ends—bell or flanged as specified under Sec. 6.

1.4.8. Detailed description of end connections if not bell or flange, or if

bell or flange dimensions are to be other than as specified in Sec. 6.

1.4.9. Class or outside diameter of pipe to be used with valves 30 in. or larger, as specified under Sec. 6.1.1.

1.4.10. Intended position of valve in line—that is, horizontal or vertical.

1.4.11. Solid bronze discs, if required, as specified under Sec. 7.2.1.

1.4.12. If desired, acceptance of O-ring stuffing box if manufacturer offers valves so designed (*see* footnote under Sec. 13.1).

1.4.13. Detailed description of wrench nuts, if not in accordance with Sec. 16.

1.4.14. Direction in which wrench nut shall turn to open—whether right (clockwise) or left (counter-clockwise).

1.4.15. Gears, if required, as specified under Sec. 17.

1.4.16. Cast-iron gears, if required, as specified under Sec. 17.2.1.

1.4.17. Whether gear cases are not to be provided, as specified under Sec. 18.

1.4.18. Position indicator, if required, as specified under Sec. 19.

1.4.19. By-pass, if required, as specified under Sec. 20. Unless otherwise specified, the position of the by-pass on the valve body shall be as shown in Fig. 3, Position A or B.

1.4.20. Spot-facing, if required, as specified under Sec. 22.2.1.

1.4.21. Special cast markings, if required, as specified under Sec. 24.

1.4.22. Manufacturer's certification of tests, if required, as stated under Sec. 26.2.

Sec. 1.5—Data to Be Furnished by the Manufacturer

1.5.1. After purchase, the manufacturer shall, if requested, furnish catalog data, including illustrations, and a schedule of parts and the materials of which they are made, in sufficient detail to serve as a guide in the assembly and taking down of the valve, as well as in ordering repair parts.

1.5.2. When required, the manufacturer shall furnish a statement of the total net assembled weight for each size of valve.

1.5.3. When required, the manufacturer shall submit for approval by the purchaser one set of certified drawings, showing the principal dimensions, construction details, and materials used for all parts of the valve. All work shall be done and all valves shall be furnished in accordance with these certified drawings, after they have been approved by the purchaser.

Section 2—Materials

Sec. 2.1—General

All materials designated hereinafter, when used in valves produced under these specifications, shall conform to the specifications designated below for each material listed. When reference is made to American Standards Assn. (ASA), American Society for Testing Materials (ASTM), or other specifications, it is understood that the latest revision thereof shall apply.

Sec. 2.2—Determination of Physical and Chemical Properties

2.2.1. The requirements of ASA, ASTM, or other standard specifications, to which reference is made elsewhere in this text, shall govern the physical and chemical characteristics of the valve components.

2.2.2. Whenever valve components are to be made in conformance with ASA, ASTM, or other specifications,

and these specifications include test requirements or testing procedures, such requirements or procedures shall be met by the valve manufacturer. The records of such tests shall, if required by purchaser, be made available to him.

Sec. 2.3—Cast Iron

2.3.1. Cast iron shall conform to ASTM Specification A126.

Sec. 2.4—Bronze *

2.4.1. Grade I cast bronze shall conform to the properties of ASTM B62.

2.4.2. Grade II cast bronze shall conform to the properties of ASTM B132, Alloy A.

2.4.3. Grade III cast bronze shall conform to the properties of ASTM B132, Alloy B.

2.4.4. Grade IV rolled bronze shall conform to the properties of ASTM B21, Alloy A (one-half hard).

2.4.5. Grade V bronze shall be sufficiently malleable to conform to dovetailed grooves when peened or rolled, and shall have a minimum compressive strength, without deformation, of 4,000 psi.

Sec. 2.5—Steel

2.5.1. Body bolts and nuts shall conform to ASTM A307, Grade B.

2.5.2. Carbon steel castings, when used, shall conform to ASTM A27 Grade U60–30.

Sec. 2.6—Babbitt

2.6.1. Babbitt metal shall conform to ASTM B23.

Section 3—General Design

Sec. 3.1—Resistance to Stress

All parts of all valves shall be designed to withstand safely, without permanent distortion and without structural damage, both the stresses resulting from an internal test pressure of 300 psi and the combined stresses resulting from the full, internal, specified, service, working water pressure as specified under Sec. 1.2, when the gates or wedge moves across the seats, under full unbalanced working water pressure from the fully closed position to the point of full opening; thence to complete closure.

Sec. 3.2—Basis of Structural Design

All parts of valves, including body and bonnet, shall be so proportioned that it will be possible to apply sufficient torque to the stem, in the closing direction, with the valve closed and with the valve internally subjected to the working water pressure, to cause the stem to fail without causing permanent distortion of any part other than the stem.

Sec. 3.3—Size of Waterway

With the valve open, an unobstructed waterway shall be afforded, the diameter of which is not less than the full nominal diameter of the valve, except that, if lugs are provided for inserting or removing the body-seat rings, they need not be cleaned out after the valve is assembled.

** Grades II, III, and IV bronze must not be used in a system in which the water has been lime softened and is distributed at a high pH, as such water will remove zinc from the bronze. These materials are specified for valve stems, guide contacts for wedge gate valves, wedges for gate valves, etc. Alternate materials acceptable to the manufacturer and to the purchaser must be used with such waters.*

Section 4—Bodies and Bonnets

Sec. 4.1—Design

4.1.1. It is recognized that some variations are unavoidable in the making of patterns and castings. In order to define what may be considered a reasonable degree of accuracy in shell thickness measurements, the following inspection limits shall be allowed:

4.1.2. Shell thickness measurements taken at points diametrically opposite each other shall, when added together and divided by two, equal or exceed the minimum metal thicknesses given in Table 1. Shell thicknesses at no point shall be more than 12½ per cent below the minimum metal thicknesses called for in Table 1, and no continuous area of deficient thickness shall exceed 12½ per cent of the superficial area of the casting.

4.1.3. All metal sections and ribbing shall be properly proportioned, and corners shall have well-rounded fillets, in accordance with the best foundry practice. In double-disc gate valves, the body and bonnet shall be designed to reduce the side clearance of the discs.

4.1.4. The valve body shall be machined and threaded for shoulder-seated (or bottom-seated) body-seat rings, with sufficient depth of thread and accuracy of seating surface to prevent leakage behind the body-seat rings.

4.1.5. The thrust-bearing recess and the stem opening in the bonnet shall be finished. In valves 16 in. in diameter and larger, the thrust-bearing recess shall be Grade I or II bronze-lined, and the stem opening shall be Grade I or II bronze-bushed.

4.1.6. In horizontal-stem valves 16 in. in diameter and larger, and in vertical-stem valves 24 in. in diameter and larger, a pair of accurately matched dowel holes and tapered or round-end dowels shall be provided in the flanges of body and bonnets to aid in assembling. Dowels shall be located at opposite ends of the flange, one near lateral center line, and other approximately 2 in. from lateral center line.

TABLE 1

Minimum Thickness of Bodies and Bonnets

Valve Diameter *in.*	Minimum Thickness* *in.*
3	0.37 ($\frac{3}{8}$)
4	0.40 ($\frac{13}{32}$)
6	0.43 ($\frac{7}{16}$)
8	0.50 ($\frac{1}{2}$)
10	0.63 ($\frac{5}{8}$)
12	0.68 ($\frac{11}{16}$)
16	0.85 ($\frac{27}{32}$)
20	0.97 ($\frac{31}{32}$)
24	1.08 ($1\frac{5}{64}$)
30	1.39 ($1\frac{13}{32}$)
36	1.54 ($1\frac{17}{32}$)
42	1.58 ($1\frac{19}{32}$)
48	1.73 ($1\frac{23}{32}$)

* The decimal value should be used when the two expressions are not exactly equivalent. The figures listed are taken from ASA A21.2 (AWWA C102), specification for cast-iron pit-cast pipe for water or other liquids. Thicknesses of valves up to and including the 36 in. are the same as those specified for Class 250 pit-cast pipe. Thicknesses of 42- and 48-in. valves are the same as those specified for Class 200 pit-cast pipe.

Sec. 4.2—Material

Bodies and bonnets of valves 10 in. and larger in size shall be made of cast iron of not less than "Class B" material as specified in ASTM A126. Bodies and bonnets of valves less than 10 in. in size shall be made of cast iron of quality not less than Class A material specified in ASTM A126.

Section 5—Bonnet Bolting

Body bolts and nuts shall conform to ASTM A307, Grade B. Bolts and nuts shall be either cadmium-plated or zinc-coated (ASTM A123), or rust-

proofed by some other process (parkerizing, sherardizing, etc.), disclosed to, and acceptable to, the purchaser. Body bolt studs shall conform to the threading and physical requirements of ASTM A307 Grade B.

Section 6—Valve Ends

Sec. 6.1—Ends for Bell-and-Spigot Pipe

6.1.1. Valves designed for installation with bell-and-spigot pipe shall be cast with bells on each end of the valve. The dimensions of the bells on valves up to and including 24 in. in diameter shall conform to those for Class C * special castings, as required by AW WA C100. On valves 30 in. and larger in size, either the bell dimensions, the class, or the outside diameter of the pipe to be used shall be specified by the purchaser.

Sec. 6.2—Ends for Flanged Pipe

The end flanges of flanged gate valves shall conform in dimensions and drilling to the standard ASA B16.1 for cast-iron flanges and flanged fittings, Class 125, unless explicitly provided otherwise in the supplementary specifications.

Section 7—Gates and Rings

Sec. 7.1—Design

7.1.1. Cast-iron gates shall be fitted with separate rings in such a manner as to preclude loosening or leaking behind the seats, with cross section sufficiently stiff to resist accidental deformation in handling and assembly.

7.1.2. Gate rings shall be rolled, peened, or pressed into grooves machined in the discs, or fastened by some other method disclosed to, and acceptable to, the purchaser.

7.1.3. Finish cuts shall be taken over the gate rings after they have been fully secured in place.

7.1.4. The width of the face of the gate rings shall not be less than that of the body-seat rings, and there shall be provided a sufficiently greater width to permit the gates to continue to seat tightly after allowing for reasonable wear of the faces of the rings, and of the various parts of the mechanism of the gate.

Sec. 7.2—Material

7.2.1. Valve gates or wedges shall be made of cast-iron or Grade I bronze, at the manufacturer's option, unless bronze is explicitly required by the purchaser's supplementary specifications.

7.2.2. Gate rings shall be made of Grade V bronze.

Section 8—Body-Seat Rings

Sec. 8.1—Design

8.1.1. Body-seat rings shall be backfaced, the threads accurately cut, and the rings shall be screwed into machined seats in the body. They shall be made with cross section sufficiently stiff to resist accidental deformation in handling and assembly.

8.1.2. The width of body-seat ring shall be sufficient to result in a bearing pressure of the gate on the body-seat ring of not more than 2,000 psi under the hydrostatic pressure of 300 psi.

* AWWA C100 Class C Bell Diameter

Size of Pipe in.	ID of Bell in.
4	5.80
6	7.90
8	10.10
10	12.20
12	14.30
16	18.80
20	23.06
24	27.32

The thickness of the body-seat ring shall be not less than 20 per cent of the width of the face as calculated from the above requirement.

Sec. 8.2—Material

Body-seat rings shall be made of Grade I bronze.

Section 9—Wedging Device

Sec. 9.1—Design

Gate valves of the double-disc type shall be equipped with a free and positive-operating internal wedging device, simple and rugged in design, which, in closing the valve, will operate (when discs are opposite the ports) to press the discs firmly against the body seats and release them therefrom before the valve starts to open.

Sec. 9.2—Material

9.2.1. Bronze used for wedges shall be Grade I, II, or III.

9.2.2. Pins and bolts in the wedging mechanism of all valves shall be Grade IV bronze.

9.2.3. In valves 16 in. in diameter and larger, all wedging surfaces shall be Grade I, II, or III bronze to bronze; in valves of diameters from 3 to 12 in., inclusive, all wedging surfaces may be Grade I, II, or III bronze to iron, but not iron to iron. At the manufacturer's option (subject to purchaser's approval), monel made to Navy Specification 46MI may be used for wedging surfaces instead of Grade I bronze.

Section 10—Guides (Wedge-Gate Valves)

In solid-wedge gate valves, tongue-and-groove guides shall be provided on the sides of the gate and in the body to keep the gate centered between the seats throughout its full length of travel. In valves 16 in. in diameter and larger, bearing of gate on guides shall have length equal to at least 50 per cent of the port diameter of the valves, and the grooves in the gate shall be Grade I, II, III, or IV bronze-faced to bear against the guides in the body. Guide contacts shall be Grade II, III, or IV bronze to bronze.

Section 11—Rollers and Tracks for Horizontal Valves

Sec. 11.1—Double-Disc Valves

11.1.1. Gate valves of double-disc type, 16 in. in diameter and larger, designed to lie horizontally in a horizontal pipeline, shall be equipped with solid (Grade I or IV) bronze or hard babbitt tracks securely fastened in body and bonnet, carrying the weight of the gates throughout their entire length of travel on rollers. Babbitt metal for tracks shall conform to ASTM B23, Grade 3.

11.1.2. In double-disc gate valves of the "rolling-disc" type, the discs will serve as rollers.

11.1.3. In double-disc valves of other than the rolling-disc type, the discs shall be carried on solid (Grade I, II, III, or IV) bronze rollers securely attached to them.

Sec. 11.2—Wedge-Gate Valves

In gate valves of the solid-wedge type, 16 in. in diameter and larger, designed to lie horizontally in a horizontal pipeline, the tongue-and-groove gate guides shall be modified with rollers or shoes to carry the weight of the wedge throughout its entire length of travel on

solid (Grade I or IV) bronze or hard babbitt tracks securely fastened in the body and bonnett. Babbitt metal shall conform to ASTM B23, Grade 3.

Sec. 11.3—Scrapers

In all valves in which rollers and tracks are used, bronze scrapers (Grade I, II, III, or IV) shall be provided to traverse the tracks ahead of the rollers in both directions of travel to remove any foreign matter which may have accumulated on the track.

Section 12—Stems and Stem Nuts

Sec. 12.1—Design

12.1.1. All stem collars shall be made integral with stems.

12.1.2. The threads of stems and stem nuts (disc bushings) shall be of the square, Acme, modified Acme or one-half V type, with a sufficient number of cuts to avoid straining the metal.

TABLE 2

Minimum Diameter of Stem

Diameter of Valve *in.*	Min. Diam. of Stem at Base of Thread *in.*
3	0.8594
4	0.8594
6	1.000
8	1.000
10	1.125
12	1.188
16	1.438
20	1.750
24	1.969
30	2.188
36	2.50
42	2.75
48	3.50

12.1.3. Stems shall be turned and threaded straight and true, and shall work true and smooth and in perfect line throughout the lift of opening and thrust of closing the valve.

12.1.4. The diameters of stems at the base of the thread shall be not less than those shown in Table 2.

12.1.5. Stems in valves up to and including 20 in. in diameter shall have a lead of not more than $\frac{1}{3}$ in. Stems in valves 24 in. and larger shall have a lead of not more than $\frac{1}{2}$ in.

Sec. 12.2—Material

12.2.1. Valve stems shall be cast, forged, or rolled bronze.

TABLE 3

*Physical Characteristics for Manganese Bronze**

	Minimum Tensile Strength *psi*	Minimum Yield Strength *psi*	Minimum Elongation in 2 in. *per cent*
Valve sizes up to and including 24 in.	60,000	20,000	15
Valve sizes 30 in. and larger	80,000	32,000	15

* For use in forged and rolled stems.

12.2.2. Bronze for cast stems shall be Grade II or III for valve sizes 24 in. and smaller, and Grade III for valve sizes 30 in. and larger.

Bronze for forged and rolled stems shall be manganese bronze having the physical characteristics given in Table 3.

12.2.3. Stem nuts shall be Grade I, II, or III bronze.

Section 13—Stuffing Boxes

Sec. 13.1—Design

13.1.1. Design of the stuffing box shall be such that the valve can be packed under pressure when in the fully open position.*

13.1.2. The stem opening, thrust-bearing recess, and bonnet face of the stuffing box shall be machined. In valves 16 in. in diameter and larger, both the stem opening and thrust-bearing recess shall be Grade I, bronze-bushed.

13.1.3. Stuffing boxes shall have a depth not less than the diameter of the valve stem. The internal diameter shall be large enough to contain adequate packing to prevent leakage around the stem.

Sec. 13.2—Material

13.2.1. The stuffing box shall be made of cast iron.

13.2.2. Bronze for the stem-collar thrust bushings shall be Grade I.

13.2.3. Stuffing box bolts and nuts shall conform to ASTM A307, Grade B. They shall be rust-proofed as is required for body bolts and nuts in Sec. 5.

Section 14—Packing

Sec. 14.1—Material

Stuffing box packing shall be made of asbestos conforming to Navy Department Specification 33–P–26–b, Type A, or flax packing conforming to Federal Specification HH—P–106c. Hemp packing shall not be used.

Sec. 14.2—Installation

Stuffing boxes shall be properly packed and ready for service when valves are delivered to the purchaser.

Section 15—Glands and Gland Bolts and Nuts

Sec. 15.1—Design

15.1.1. The gland assembly shall be of solid, solid-bushed, or two-piece design.

15.1.2. Gland flanges (followers) may be formed as a flanged end on the gland, or as a separate part.

Sec. 15.2—Material

15.2.1. Glands for valves of sizes 12 in. and smaller shall be made of Grade I, II, III, IV, or ASTM B124 bronze. Glands for valves of sizes larger than 12 in. in diameter may be made of iron with bushings of Grade I, II, III, IV, or ASTM B124 bronze. Glands which are either cadmium-plated or zinc-coated (ASTM A123) or rust-proofed by some other process, such as parkerizing or sherardizing, disclosed to, and acceptable to the purchaser, may be furnished.

15.2.2. If a gland flange (follower) is used, it may be made of the same material as the gland.

15.2.3. Gland bolts shall be made either of Grade II or IV bronze or rust-proofed steel according to Sec. 5. Gland bolt nuts shall be made of Grade II, III, or IV bronze.

* Some manufacturers offer a valve provided with an O-ring stuffing box. The purchaser may accept this design, if he desires (*see* Sec. 1.4.12).

Section 16—Wrench Nuts

Sec. 16.1—Design

16.1.1. Wrench nuts shall be fitted to the top of the valve stem, and secured in position by nut, pin, or key.

16.1.2. Unless otherwise explicitly required by the purchaser's supplementary specifications, the wrench nuts shall be $1\frac{15}{16}$ in. square at the top, 2 in. square at the base, and $1\frac{3}{4}$ in. high. Nuts shall have a flanged base upon which shall be cast an arrow at least 2 in. long showing the direction of opening, and the word "OPEN," in $\frac{1}{2}$-in. or larger letters, shall be cast on the nut to indicate clearly the direction to turn the wrench when opening the valve.

16.1.3. The flanged base of the nut may be shaped or cut away to permit access from the ground surface to the packing gland bolts with an extension socket wrench.

Sec. 16.2—Material

Wrench nuts shall be made of cast iron.

Section 17—Gearing

Sec. 17.1—Design

17.1.1. Gears shall be accurately formed and smooth-running, with bronze spindles running in bronze, or with babbitt-lined bearings. Gear teeth shall be machine cut.

17.1.2. Gear ratios shall not be less than those shown in Table 4.

TABLE 4

Gear Ratios

Valve Diameter *in.*	Gear Ratio
16	2:1
20	2:1
24	2:1
30	3:1
36	3:1
42	4:1
48	4:1

Sec. 17.2—Material

17.2.1. Geared valves shall be equipped with cut-tooth steel gears, unless cut-tooth cast-iron gears are explicitly required by the purchaser's supplementary specifications. Pinions with cast-iron gears shall be steel. Material for steel gears shall conform to the physical requirements of Specifications ASTM A27, Grade U-60-30.

17.2.2. Babbitt lining for bearings shall conform to ASTM B23, Grade 8.

Section 18—Gear Cases

When geared valves are furnished, enclosed gear cases are required unless definitely excluded by the purchaser's supplementary specifications. Two types may be furnished—the "extended type" or the "totally enclosed type." The extended type shall be attached to the bonnet of the valve in such manner as to permit repacking of the stuffing box of the valve without disassembly. The totally enclosed type shall be attached to the bonnet to enclose both stuffing box and gearing.

Section 19—Indicators

When required by purchaser's supplementary specifications, geared valves shall be equipped with indicators to show the position of the gate in rela-

tion to the ports. The indicator mechanism shall be all bronze, enclosed in a dirt-proof cast-iron case, and mounted in such position that the indicator can be easily seen by the man operating the valve.

Section 20—By-passes

By-passes, when required by purchaser's supplementary specifications, shall be of the sizes shown in Table 5 and shall be located in one of the positions indicated in Fig. 3. By-pass valves shall be the same size as the by-pass and shall conform to the requirement of these specifications for the specific valve size used.

TABLE 5

Size Requirements of By-passes

Valve Diameter *in.*	By-pass Diameter *in.*
16–20	3
24–30	4
36–42	6
48	8

Section 21—Gaskets

Sec. 21.1—Design

Gaskets shall be full-cut, with holes to pass bolts, or cut to fit inside of bolts, and shall be used on all flanged joints intended to be watertight.

Sec. 21.2—Material

Gasket material shall be either sheet asbestos, a rubber composition, or paper free from corrosive ingredients, either alkaline or acid.

Section 22—Workmanship

Sec. 22.1—General

All workmanship employed in the fabrication and assembly of valves covered by this specification shall be first-class in every respect. Valve parts shall be designed, and manufacturing tolerances set, to provide interchangeability in the products of any one manufacturer between units of the same size and type, except the individual fit of the wedge in the body. When assembled, valves manufactured in accordance with these specifications shall be well-fitted, smooth-running, and watertight.

Sec. 22.2—Details

22.2.1. Unless spot facing is required by supplementary specifications, the bolt holes of the end flanges shall not be spot-faced, except as specified in ASA Standard B16.1. (See Note at end.)

22.2.2. All castings shall be clean and sound, without defects which will impair their service. No plugging, welding, or repairing of such defects will be allowed.

Section 23—Painting

An asphalt varnish made to comply with Federal Specification TT–V–51a or Army & Navy Specification JAN–P–450 shall be applied to the ferrous part of the valves, except finished or bearing surfaces. Surfaces shall be clean, dry, and free from grease before painting. Two coats shall be applied both to the inside and outside ferrous metal.

Section 24—Markings

Markings shall be cast on the bonnet or body of each valve showing the manufacturer's name or mark, the year the valve casting was made, the size of the valve, and the designation of working water pressure (150 W or 175 W). Special markings in addition to these can be supplied, when specified by supplementary requirements, upon agreement between purchaser and manufacturer.

Section 25—Testing

Sec. 25.1—Performance Tests

After completion each gate valve shall be tested at the shop for performance in operation, and for watertightness and resistance to distortion under internal pressure. Each valve shall be operated in the position that it will assume in service and for the full length of gate travel in both directions, to demonstrate the free and perfect functioning of all parts in the intended manner. Any defects of workmanship shall be corrected and the test repeated until satisfactory performance is demonstrated.

Sec. 25.2—Hydrostatic Tests

25.2.1. Each 3- to 12-in. valve, inclusive, shall be subjected to hydrostatic test under pressures of both 300 and 175 psi. Each 16- to 48-in. valve, inclusive, shall be subjected to test pressures of both 300 and 150 psi. The tests shall be conducted in the following manner:

25.2.2. For double-disc gate valves, the hydrostatic pressure shall be applied inside the bonnet with gates closed.

25.2.3. For solid-wedge gate valves, the 150- or 175-psi pressure (as required in 25.2.1) shall be applied, through bulkheads, alternately to each side of the closed gate, with the opposite side open for inspection; the 300-psi pressure shall be applied with both ends bulkheaded and the gate open.

25.2.4. Under the 150 or 175 psi test (as required in 25.2.1), all joints and seats shall be perfectly watertight. Under the 300-psi test, there shall be no leakage through the metal, nor through the flanged joints, nor shall any cast part be permanently deformed.

Section 26—Inspection and Rejection

Sec. 26.1—Purchaser's Inspector

All work under these specifications shall be subject to inspection and approval by the purchaser's duly authorized engineer or inspector, who shall at all times have access to all places of manufacture where materials are being produced or fabricated or tests are being conducted, and who shall be accorded full facilities for inspection and observation of tests. Any gate valve or part which he may condemn as not conforming to the requirements of these specifications shall be made satisfactory or shall be rejected and replaced.

Sec. 26.2—Manufacturer's Certification

If the purchaser has no inspector at the plant, the manufacturer shall, if requested at the time the order is placed, certify that the required tests on the various materials and on the completed valve have been made, and that the results of all tests conform to the requirements of these specifications.

Section 27—Preparation for Shipment

Sec. 27.1—General

Valves shall be complete in all details when shipped. The manufacturer shall use care in preparing them for shipment so that no damage due to the manufacturer's negligence will occur in handling or in transit. Valves must be drained and completely closed before shipment.

Sec. 27.2—Large Valves

Valves 24 in. and larger in diameter shall be securely bolted or otherwise fastened to skids in such manner that they may be safely unloaded with a crane.

Notes

The valve illustrations (Fig. 1–3) point out some of the stipulations of these specifications, but show also some variations of commercial design on which the purchaser may exercise a choice. The purchaser should state all his requirements at the time of purchase. No one manufacturer will be prepared to furnish valves in all applicable variations.

Requirements for spot-facing, as given in Sec. 22.2.1, suggest reference to Introductory Note 12 from American Standard ASA B16.1:

Spot Facing. Flanges. The bolt holes of these cast-iron flanges need not be spot-faced for ordinary service except as follows: in sizes 12 in. and smaller when rough flanges, after facing, are oversize more than $\frac{1}{8}$ in. in thickness, they shall be spot-faced to the specified thickness of flange (minimum) with a plus tolerance of $\frac{1}{16}$ in. In sizes 14 to 24 in., inclusive, when rough flanges, after facing, are oversize more than $\frac{1}{16}$ in. in thickness, they shall be spot-faced to the specified thickness of flange (minimum) with a plus tolerance of $\frac{1}{16}$ in. In sizes 30 in. and larger when rough flanges, after facing, are oversize more than $\frac{1}{4}$ in. in thickness, they shall be spot-faced to the specified thickness of flange (minimum) with a plus tolerance of $\frac{1}{8}$ in.

Spot-Facing. Fittings. The bolt holes of the flanges on these cast-iron fittings need not be spot-faced on sizes smaller than 18 in. for ordinary service, except as required for oversize thickness of flanges as indicated above. The bolt holes of all flanges on fittings 18 to 24 in., inclusive, shall be spot-faced to the specified thickness of the flange (minimum) with a plus tolerance of $\frac{1}{16}$ in. The bolt holes of all flanges on fittings 30 to 48 in., inclusive, shall be spot-faced to the specified thickness of the flange (minimum) with a plus tolerance of $\frac{1}{8}$ in.

Where spot-facing of flanges and fittings is necessary, the spot-facing diameter shall be in accordance with MSS Standard Practice SP-9-1947.

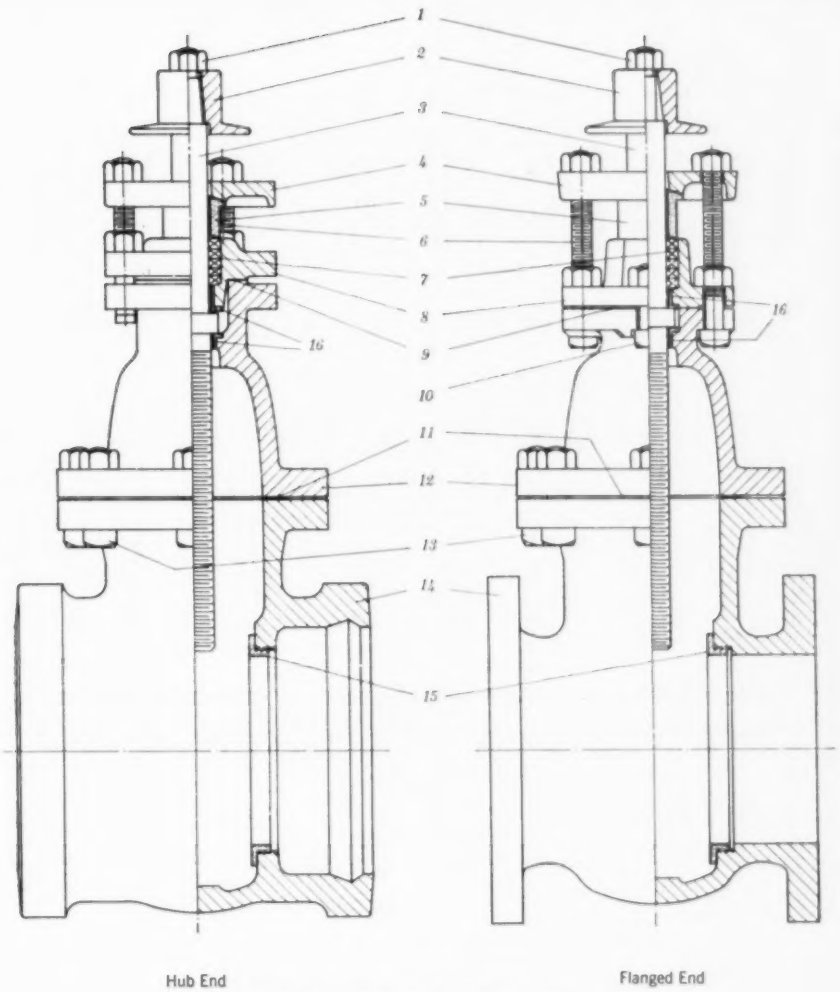

Fig. 1. Double-Disc Gate Valves With Nonrising Stems

The numbers on the figure refer to the following parts:

1—*Nut for wrench nut*
2—*Wrench nut*
3—*Stem*
4—*Gland flange (or follower)*
5—*Gland*
6—*Gland bolts and nuts*
7—*Stem packing*
8—*Stuffing box*
9—*Stuffing box gasket*
10—*Stuffing box bolts and nuts or studs and nuts*
11—*Bonnet gasket*
12—*Bonnet*
13—*Bolts, bolt-studs, and nuts for bonnet*
14—*Body*
15—*Seat ring (body)*
16—*Stem collar thrust bushing*

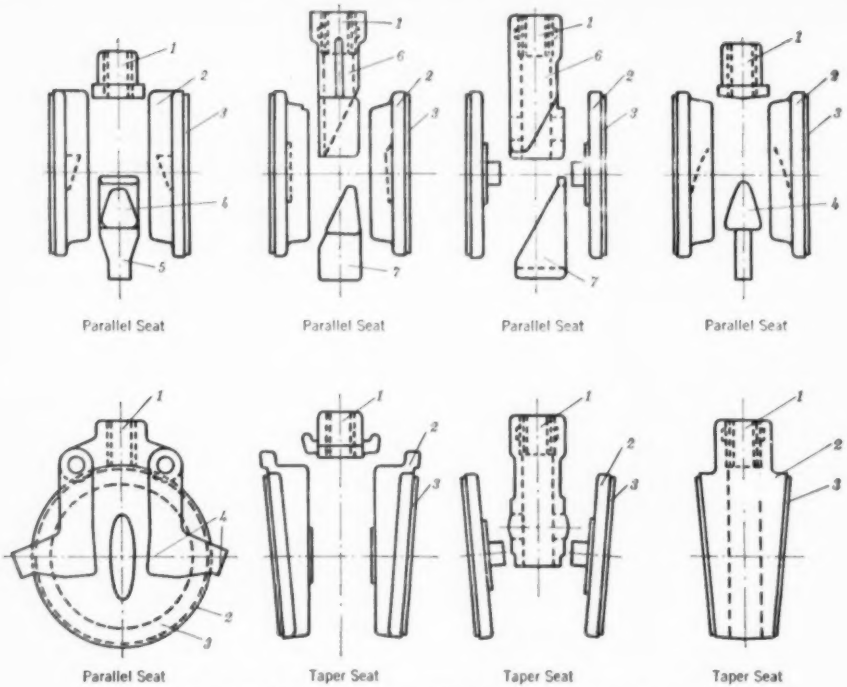

Fig. 2. Various Double Disc Assemblies and a Solid Wedge Assembly

All the figures illustrate double disc assemblies except the lower right hand figure which illustrates a wedge type assembly. The numbers on the figure refer to the following parts:

1—Stem nut
2—Disc
3—Disc ring
4—Wedge
5—Wedge hook
6—Top wedge
7—Bottom wedge

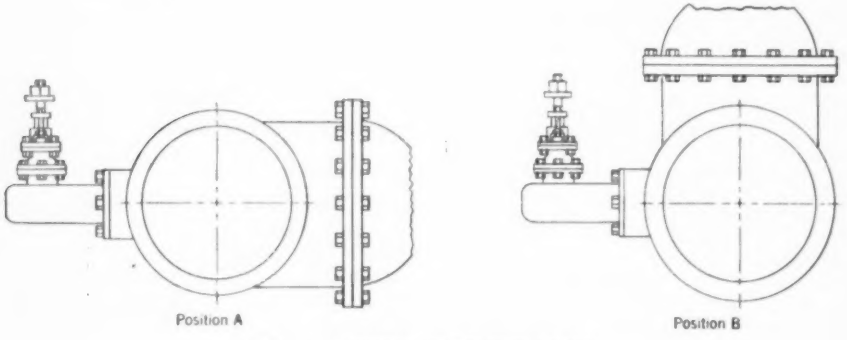

Fig. 3. Location of By-pass Valve

In Position A the main valve is installed horizontally, and in Position B it is installed vertically.

UDC 621.774.1

ASA A21.10-1952
(AWWA C110-52)

American Standard Specifications
for
SHORT-BODY CAST-IRON FITTINGS, 3 INCH TO 12 INCH, FOR 250-PSI WATER PRESSURE PLUS WATER HAMMER

PUBLISHED BY AMERICAN WATER WORKS ASSOCIATION, INC.

APPROVED BY SPONSORS

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Foreword

For a brief history of the development of standard specifications for cast-iron pipe and fittings for water, for the organization and program of the Sectional Committee (A21) on Specifications for Cast Iron Pipe and Fittings which developed the specifications contained herein, and for a description of the other specifications issued or in preparation by this sectional committee, reference should be made to the Foreword of the "American Recommended Practice Manual for the Computation of Strength and Thickness of Cast Iron Pipe (ASA A21.1)."

The short-body fittings described in the specifications which follow were developed to meet a growing demand for lighter, cheaper and more compact fittings than those of earlier standard specifications for bell-and-spigot fittings for water, fittings better adapted to use in distribution work in city streets congested with other utility structures. This need for more compact fittings had led to a variety of special designs by different municipalities and manufacturers.

The radical change in design raised questions of strength and hydraulic properties which were studied exhaustively by Committee A21. Strength was investigated, with numerous bursting tests in each case, by Dean M. L. Enger and Prof. W. M. Lansford of the Dept. of Theoretical and Applied Mechanics, University of Illinois (unpublished), and by the American Cast Iron Pipe Co. representing the Cast Iron Pressure Pipe Institute of the manufacturers (unpublished). Hydraulic losses, in comparison with losses in fittings of the current A.W.W.A. long-body patterns, were measured at the Cornell University Engineering Experiment Station by Prof. Ernest W. Schoder and Prof. Arthur N. Vanderlip; and an economic comparison of the short-body and the A.W.W.A. types, as they would be used in a typical distribution system, was made by Allen T. Ricketts and Thomas H. Wiggin. Both of these studies of hydraulic losses were published in Cornell University Engineering Experiment Station Bulletin No. 20, September 1935 (102 pages, $1.25). These studies, for 12-in. and smaller fittings, demonstrated not only the strength of the short-body designs, but also that these short fittings are slightly superior economically in distribution systems, considering friction losses, the cost of power for pumping, and installation costs. Longer-radius bends show somewhat smaller losses of head, but the difference is so small for usual distribution velocities, and the use of bends in distribution systems, except where space is limited, is so infrequent, that this difference may be disregarded.

Since cast-iron tees and crosses, especially those with equal outlets, defy accurate stress analysis, the designs were developed on the basis of numerous bursting tests, with allowances for water hammer, for foundry tolerance and for a loss in thickness of 0.08 in. by corrosion. These fittings are of one class only, for a static working water pressure of 250 psi plus water hammer, with or without ordinary earth loads, and with a factor of safety of about 2½.

The designs contemplate all bell fittings. The spigots shown in Fig. 10.1 (*see* p. 10) will be substituted for one or more bells as ordered. Fittings of the same body dimensions and laying lengths, with flange ends or ends for mechanical joints, may also be ordered under these specifications.

UDC 621.774.1

ASA A21.10-1952
(AWWA C110-52)

American Standard Specifications for

Short-Body Cast-Iron Fittings, 3 Inch to 12 Inch, for 250-psi Water Pressure Plus Water Hammer

This specification covers 3-in. to 12-in. short-body cast-iron fittings for water pressure of 250 psi plus water hammer as specified in the "American Recommended Practice Manual for the Computation of Strength and Thickness of Cast Iron Pipe" (ASA A21.1).

Sec. 10–1—Description of Fittings

Fittings shall be made with all bell ends or such other type of ends as may be agreed upon at the time of purchase. Fittings with all bell ends or with spigot ends shall accurately conform to the dimensions given in the tables accompanying and forming a part of these specifications. Fittings with other types of ends shall comply with the dimensions agreed upon but in all other respects shall fulfill the specifications hereinafter given.

Sec. 10–2—Casting of Fittings

Fittings shall be molded from accurate patterns. They shall not be stripped while sufficiently hot to be injured by subsequent cooling.

Sec. 10–3—Quality of Iron

10–3.1. All fittings shall be made of cast iron of good quality, and of such character and so adapted in chemical composition to the thickness of the fittings to be cast that the iron in the fittings shall be strong, tough, resilient, of even grain and soft enough for satisfactory drilling and cutting and it shall comply with the physical specifications given in Sec. 10–14 and 10–15. The metal shall be remelted in a cupola or other suitable furnace.

10–3.2. The iron in the fittings shall not contain more than 0.90 per cent of phosphorus nor more than 0.12 per cent of sulfur. Samples for chemical analysis shall be taken by drilling completely through from skin to skin each of the acceptance test specimens; but not to exceed three specimens per heat.

Sec. 10–4—Quality of Castings

The fittings shall be smooth and free from scales, lumps, blisters, sand holes and defects of every nature which unfit them for the use for which they are intended. No plugging, filling, burning-in or welding will be allowed except as permitted by the purchaser.

Sec. 10–5—Foundry Records

10–5.1. *Casting.* A record of the melting and pouring temperatures of the iron shall be furnished the purchaser if requested.

10–5.2. *Chemical analyses.* Chemical analyses shall be made by the manufacturer from each heat to determine total carbon, manganese, phosphorus, sulfur and silicon; duplicate

copies of test reports shall be furnished the purchaser on request.

Sec. 10–6—Marking of Fittings

Every fitting shall have distinctly cast upon it the initials of the maker's name, and, if requested by the purchaser, figures showing the year in which it was cast. Nominal diameters of openings shall be cast on all fittings and the fraction of the circle on all bends; also any initials, not exceeding four, which may be required by the purchaser. The letters and figures shall be cast on the outside and have dimensions not less than those indicated below:

Fitting Diam. *in.*	Height of Letters *in.*	Relief *in.*
3–10	2	$\frac{3}{32}$
12	$1\frac{1}{4}$	$\frac{3}{32}$

The weight and the class shall be conspicuously painted in white on the inside or outside of each fitting after the coating has become hard.

Sec. 10–7—Inspection by Purchaser

10–7.1. *Definition of "Purchaser."* Wherever the word "Purchaser" is used herein it shall be understood to mean the actual purchaser of the fittings or his authorized agents acting within the scope of the duties entrusted to them.

10–7.2. *Power of purchaser to inspect.* The purchaser shall have free access at all times to all parts of any manufacturing plant which concern the manufacture of articles to be made for him. He may inspect the material, pattern work, molding, casting, coating and lining of the fittings. The forms, sizes, uniformity and conditions of all fittings herein referred to shall be subject to his inspection and approval, and he may reject any fitting which is not in conformity with the specifications or drawings. Any fitting rejected shall be marked "rejected," and any marks pertaining to the purchaser shall be chipped or erased from such fitting.

10–7.3. *Manufacturer to furnish men and materials.* The manufacturer shall provide all tools, testing equipment, materials, labor and facilities necessary for the required testing, inspection and weighing of the fittings at the foundry.

10–7.4. *Report of purchaser's inspection.* The purchaser shall make written report daily at the foundry office of all fittings rejected, noting causes for rejection.

Sec. 10–8—Inspection and Certification by Manufacturer

Should the purchaser have no inspector at the works, the manufacturer shall, if required by the purchaser, furnish a sworn statement that the inspection and all of the tests have been made as specified, this statement to contain the results of all specified tests.

Sec. 10–9—Fittings to Be Delivered Sound

All the fittings must be delivered in all respects sound and conformable to these specifications. The inspection shall not relieve the manufacturer of any of his obligations in this regard, and any defective fitting which may have passed the purchaser at the works or elsewhere shall be at all times liable to rejection when discovered, until the final completion and adjustment of the contract; provided, however, that the manufacturer shall not be held liable for fittings found to be cracked after they have been accepted at the agreed point of delivery, unless there shall be unmistakable evidence that the casting

was originally defective or damaged before acceptance. Care shall be taken in handling the fittings not to injure the coating or lining, and no material of any kind shall be placed in the fittings during transportation or at any other time after they have received the coating or lining.

Sec. 10–10—Tolerances or Maximum Permitted Variations From Standard

10-10.1. *Tolerances in diameter.* All sockets and spigots shall be tested by circular gages. All fittings shall be rejected which are defective in joint room, or which vary more than 0.12 in. from standard dimensions in the diameters of the sockets and the outside diameters of spigots.

10–10.2. *Tolerances in thickness.* No variations below the standard thickness shall be permitted for 10-in. by 10-in., 12-in. by 12-in. and 12-in. by 10-in. tees and crosses. For other fittings, variations below the standard thickness shall not be greater than those shown in the following table and note:

Nom. Diameter *in.*	Minus Tolerance *in.*
3, 4 and 6	0.10
8, 10 and 12	0.12

Note: Variations from the standard thickness of 0.02 in. in excess of the allowances above given shall be permitted for spaces not exceeding 8 in. in length in any direction.

10–10.3. *Allowable percentage of variation in weight.* No fitting shall be accepted the weight of which shall be less than the standard weight by more than 10 per cent, and no excess above the standard weight of more than 10 per cent will be paid for.

Sec. 10–11—Cleaning and Inspecting

All fittings shall have gates, fins and other roughnesses chipped or ground off and shall be thoroughly cleaned, checked as to dimensions and also subjected to a careful surface inspection and a hammer test before being coated or lined.

Sec. 10–12—Weighing

Each fitting shall be weighed and the weight and class conspicuously painted on the outside or inside of the bell or spigot end. Fittings which are to be lined with cement mortar or coated on the inside or outside, or both, with bituminous enamel or other special material shall be weighed before the application of such a lining or coating. If desired by the purchaser, fittings not lined or coated with cement mortar, bituminous enamel or other special material shall be weighed after delivery and the weights so ascertained shall be used in the final settlement, provided such weighing is done by a legalized weighmaster. Unless otherwise stated in the contract, a ton shall be 2,000 lb avoirdupois.

Sec. 10–13—Linings and Exterior Coatings

Any particular lining or coating which is to be applied to the fittings shall be specified in the agreement made at the time of purchase. Separate specifications for cement-mortar lining (ASA A21.4, also known as AWWA C104) have been provided in connection with these specifications for fittings.

No fittings for water works service shall be furnished without protective coating unless specifically ordered by the purchaser.

Sec. 10–14—Test of Material

The acceptability of the iron used in the fittings shall be determined by testing bars cast from the same iron as the fittings. The observations and the computed results hereinafter required shall be recorded, and, if requested, reported to the purchaser.

Sec. 10–15—Test Bars

10–15.1. *Dimensions.* Test bars shall be 2 in. wide, 1 in. thick and not less than 26 in. long. Individual test bars may vary as much as 2 per cent from the standard width or standard thickness, or both, but the patterns and molding practice shall be such that the errors shall in general not exceed 1 per cent.

10–15.2. *Methods of casting.* The bars shall be cast vertically in well faced, dry sand molds provided with a suitable pouring basin and mounted on a suitable refractory foundation. Metal for the bars shall be obtained by using a small, heated ladle taking its metal from the main ladle from which the fittings are to be poured and after all alloys and other additional metal, except cast iron for cooling, have been added to the main ladle and become melted. The bars shall not be removed from the mold before they have cooled to 500 F.

10–15.3. *When cast and to what fittings applicable.* Except as hereinafter provided for special cases, one pair of test bars of the metal used shall be cast with iron from the first ladle, another pair with iron from the approximately middle ladle and a third pair with iron from the last ladle of iron taken during a day's run or heat, from the cupola in which the iron for the fittings is melted. If the heat lasts for more than six hours, then additional pairs of bars shall be cast at approximately uniform intervals so as to give an extra pair of bars for each three hours during which the heat lasts in excess of six hours. In case the charging of the cupola is to be changed for one or more times during the day's run or heat in order to produce a different iron, the time of taking test bars shall be varied in such a way as to obtain representative tests of the iron at least at the beginning and end of each period during which the iron is intended to be constant in quality; and in case such period exceeds four hours, additional pairs of bars shall be taken at such times as will provide a pair of bars for each two hours during which this special mixture is used. At least one bar from each pair shall be broken, but the manufacturer shall have the right to break both bars, in which case the better bar shall be taken as representative. Bars showing flaws in fracture may be disregarded.

10–15.4. *Test bar requirements to indicate acceptable iron.* In order that the iron shall be acceptable, the average results from the single bars representing the respective pairs of bars cast during the heat or period shall comply with the requirements hereinafter specified, and, in addition, no representative bar shall be more than 5 per cent below the minimum requirements in either corrected breaking load or corrected deflection.

10–15.5. *Method of testing.* The bars shall be broken as beams by placing them flatwise on supports 24 in. apart and applying the load at the center of the span. The breaking load and the corresponding deflection shall be observed and recorded.

10–15.6. *Correcting observed breaking loads and deflections.* The bars shall be measured at the point of ap-

plication of the load and the results corrected to standard 2-in. by 1-in. cross section by the conventional beam formula as follows:

Corrected breaking load

$$= \text{Observed breaking load} \times \frac{2}{bd^2}$$

Corrected deflection at breaking = Observed deflection at breaking $\times d$

where b is the measured width and d is the measured depth of the bar at the point of application of the load. In the formulas above, the deflection and all dimensions are in inches.

10–15.7. *Requirements on strength and deflection of 2-in. by 1-in. bars.* In order to indicate acceptable metal, the corrected breaking loads and deflections of the representative 2-in. by 1-in. test bars for a given heat or period, interpreted as provided in Sec. 10–15.4 above, shall comply with the following requirements:

Minimum center breaking load:

2,300 lb

Minimum center deflection at breaking:

$0.30 + 0.0001$ (breaking load $- 2{,}300$) in.

TABLE 10.1

Weights of Short-Body Fittings

Tees and Crosses

Nom. Diam. *in.*		Weight *lb*	
Run	Branch	Tee	Cross
3	3	80	105
4	3	100	125
4	4	105	140
6	3	140	165
6	4	150	180
6	6	160	210
8	3	200	225
8	4	210	240
8	6	220	265
8	8	240	305
10	3	280	305
10	4	290	320
10	6	300	350
10	8	320	390
10	10	370	465
12	3	365	390
12	4	375	405
12	6	385	435
12	8	405	475
12	10	460	555
12	12	485	600

Bends

Nom. Diam. *in.*	Weight—*lb*			
	90°	45°	22½°	11¼°
3	55	50	50	50
4	70	65	65	65
6	110	100	100	100
8	165	145	145	145
10	230	200	200	200
12	305	270	270	270

Reducers

Nom. Diam.—*in.*		Weight *lb*
Large	Small	
4	3	55
6	3	75
6	4	80
8	3	100
8	4	110
8	6	125
10	3	125
10	4	135
10	6	150
10	8	170
12	3	160
12	4	165
12	6	185
12	8	210
12	10	235

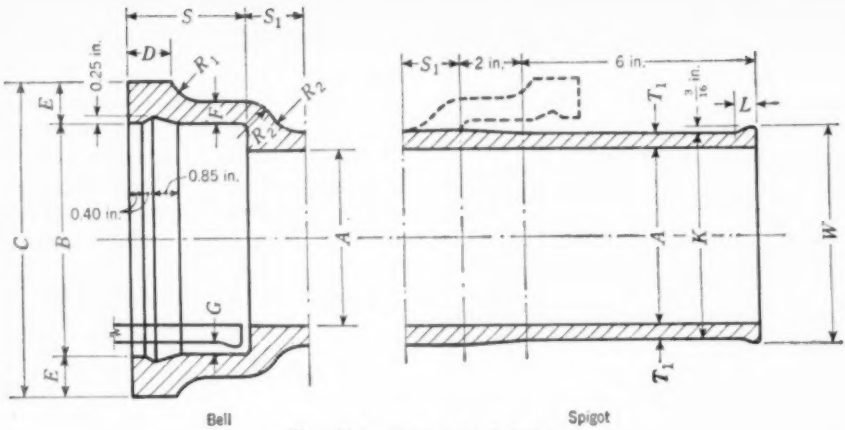

FIG. 10.1. Bells and Spigots

Bell and Spigot Dimensions

Nom. Diam. in.	A	B	C	D	E	F	G	S_1	K	L	R_1*	R_2†	S	T_1	W‡
3	3.00	4.66	7.26	1.25	1.30	0.65	0.35	1.50	3.96	0.75	0.98	1.00	3.50	0.48	4.34
4	3.96	5.70	8.30	1.50	1.30	0.65	0.40	2.00	4.90	0.75	0.98	1.05	4.00	0.47	5.28
6	6.00	7.80	10.60	1.50	1.40	0.70	0.40	2.00	7.00	0.75	1.05	1.10	4.00	0.50	7.38
8	8.10	10.00	13.00	1.50	1.50	0.75	0.41	2.00	9.18	1.00	1.12	1.16	4.00	0.54	9.56
10	10.04	12.10	15.30	1.50	1.60	0.80	0.42	2.00	11.25	1.00	1.20	1.22	4.00	0.60	11.63
12	12.00	14.20	17.60	1.50	1.70	0.85	0.42	2.00	13.35	1.00	1.28	1.27	4.00	0.68	13.73

* $R_1 = 1.5(E - F)$. † $R_2 = F + G$. ‡ $W = K + 0.38$.

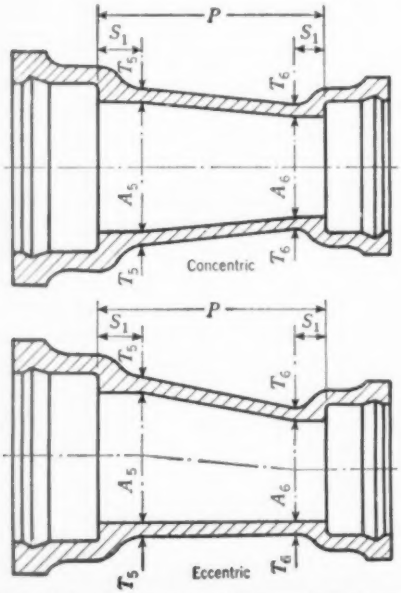

FIG. 10.2. Concentric and Eccentric Reducers

*Standard Short-Body Reducers**

Size in.	A_5	A_6	T_5	T_6	P
4×3	3.96	3.00	0.52	0.48	7.00
6×3	6.00	3.00	0.55	0.48	9.00
6×4	6.00	3.96	0.55	0.52	9.00
8×3	8.10	3.00	0.60	0.48	11.00
8×4	8.10	3.96	0.60	0.52	11.00
8×6	8.10	6.00	0.60	0.55	11.00
10×3	10.04	3.00	0.68	0.48	12.00
10×4	10.04	3.96	0.68	0.52	12.00
10×6	10.04	6.00	0.68	0.55	12.00
10×8	10.04	8.10	0.68	0.60	12.00
12×3	12.00	3.00	0.75	0.48	14.00
12×4	12.00	3.96	0.75	0.52	14.00
12×6	12.00	6.00	0.75	0.55	14.00
12×8	12.00	8.10	0.75	0.60	14.00
12×10	12.00	10.04	0.75	0.68	14.00

* S_1 equals 1.5 in. for 3-in. size; S_1 equals 2.0 in. for 4-in. through 12-in. size. For bell and spigot dimensions, see Fig. 10.1.

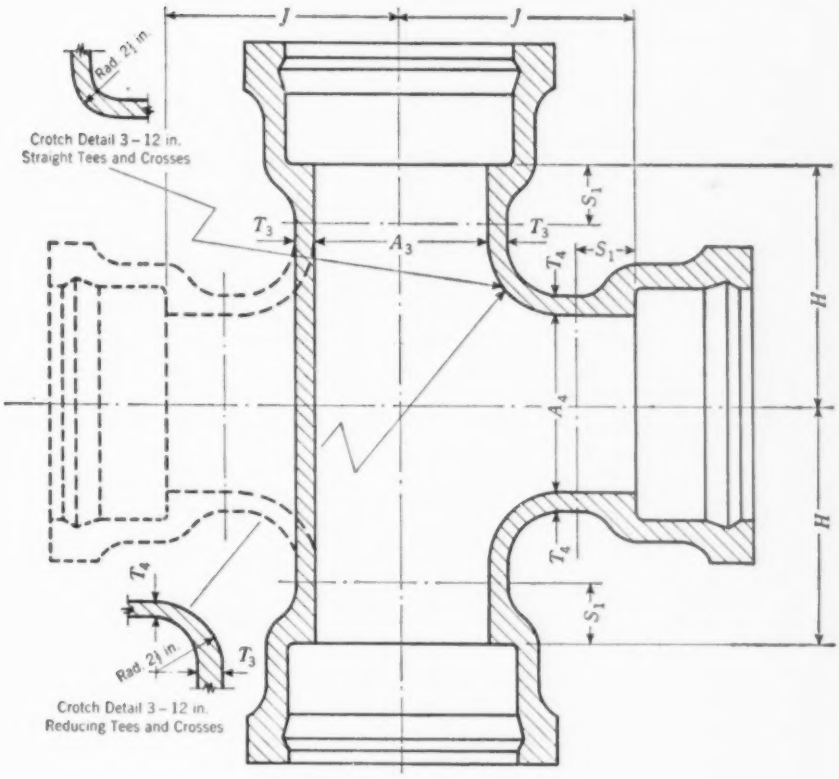

FIG. 10.3. Tees and Crosses

*Standard Short-Body Tees and Crosses**

Size in.	A_3	A_4	H	J	T_3	T_4	Size in.	A_3	A_4	H	J	T_3	T_4
3×3	3.00	3.00	5.5	5.5	0.48	0.48	10×4	10.04	3.96	11.00	11.00	0.68	0.52
4×3	3.96	3.00	6.5	6.5	0.52	0.48	10×6	10.04	6.00	11.00	11.00	0.68	0.55
4×4	3.96	3.96	6.5	6.5	0.52	0.52	10×8	10.04	8.10	11.00	11.00	0.68	0.60
6×3	6.00	3.00	8.0	8.0	0.55	0.48	10×10	10.04	10.04	11.00	11.00	0.80	0.80
6×4	6.00	3.96	8.0	8.0	0.55	0.52	12×3	12.00	3.00	12.00	12.00	0.75	0.48
6×6	6.00	6.00	8.0	8.0	0.55	0.55	12×4	12.00	3.96	12.00	12.00	0.75	0.52
8×3	8.10	3.00	9.0	9.0	0.60	0.48	12×6	12.00	6.00	12.00	12.00	0.75	0.55
8×4	8.10	3.96	9.0	9.0	0.60	0.52	12×8	12.00	8.10	12.00	12.00	0.75	0.60
8×6	8.10	6.00	9.0	9.0	0.60	0.55	12×10	12.00	10.04	12.00	12.00	0.87	0.80
8×8	8.10	8.10	9.0	9.0	0.60	0.60	12×12	12.00	12.00	12.00	12.00	0.87	0.87
10×3	10.04	3.00	11.00	11.00	0.68	0.48							

* S_1 equals 1.5 in. for 3-in. size; S_1 equals 2.0 in. for 4 in. through 12-in. size. For bell and spigot dimensions see Fig. 10.1.

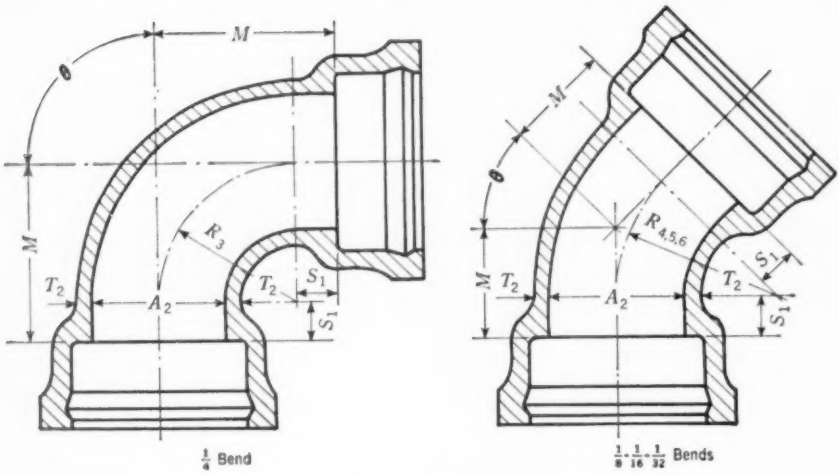

FIG. 10.4. Short-Body Bends

*Standard Short-Body Bends**

Size *in.*	All Bends		¼ Bend $\theta = 90°$		⅛ Bend $\theta = 45°$		1/16 Bend $\theta = 22\frac{1}{2}°$		1/32 Bend $\theta = 11\frac{1}{4}°$	
	A_2	T_2	M	R_3	M	R_4	M	R_5	M	R_6
3	3.00	0.48	5.50	4.00	3.00	3.62	3.00	7.56	3.00	15.25
4	3.96	0.52	6.50	4.50	4.00	4.81	4.00	10.06	4.00	20.31
6	6.00	0.55	8.00	6.00	5.00	7.25	5.00	15.06	5.00	30.50
8	8.10	0.60	9.00	7.00	5.50	8.44	5.50	17.63	5.50	35.50
10	10.04	0.68	11.00	9.00	6.50	10.88	6.50	22.62	6.50	45.69
12	12.00	0.75	12.00	10.00	7.50	13.25	7.50	27.62	7.50	55.81

* S_1 equals 1.5 in. for 3-in. size; S_1 equals 2.0 in. for 4-in. through 12-in. size For bell and spigot dimensions see Fig. 10.1.

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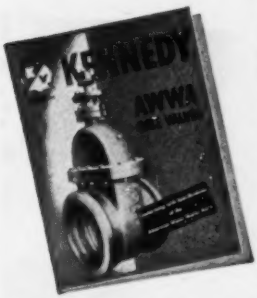

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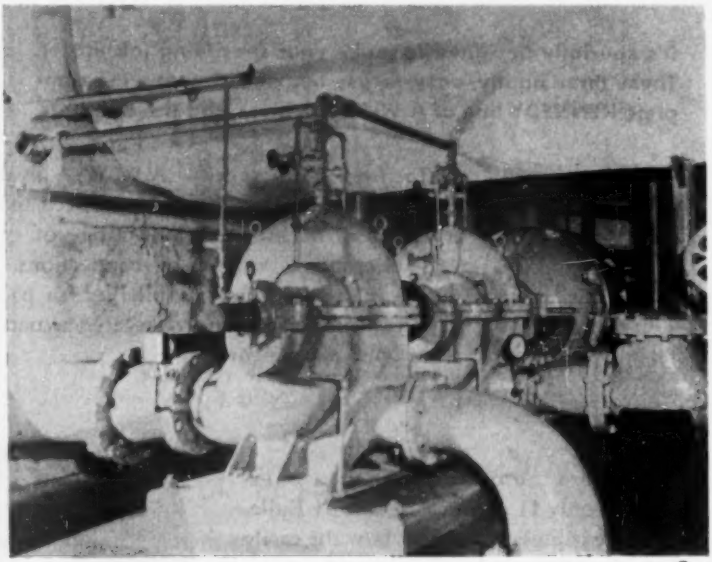

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A Dresser-coupled steel line delivers water cheaper...

The cheapest way to deliver water to the place where it turns into revenue is with a Dresser-coupled steel line—the line that

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Strong, shatterproof, yet lighter in weight, steel pipe swings into place easily. Each section goes as far as several sections of more cumbersome alternate pipe. You have fewer joints, and those more easily and quickly made with Dresser Couplings. Your line is in service sooner . . . you save costly man-hours.

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Eddy Valve Co.

WATERFORD NEW YORK

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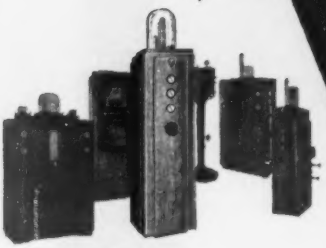

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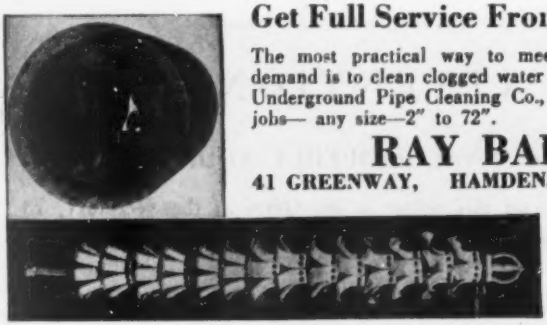

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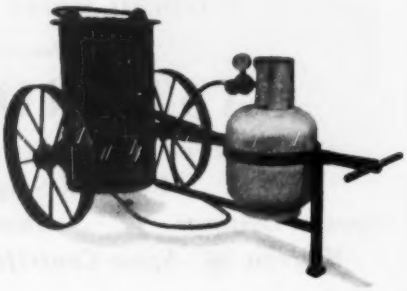

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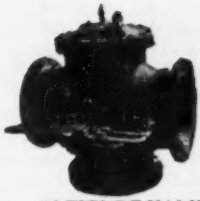

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Maintains desired discharge pressure regardless of change in rate of flow

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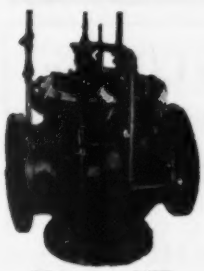

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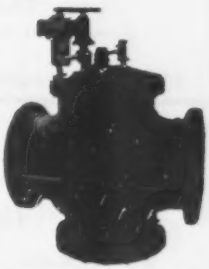

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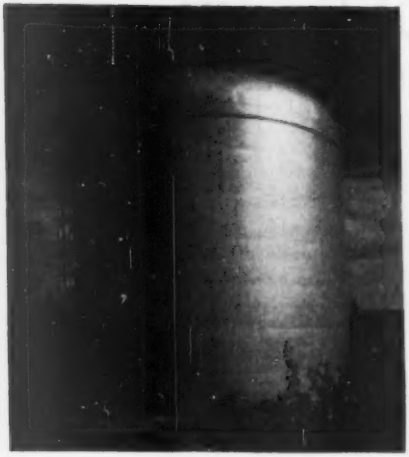

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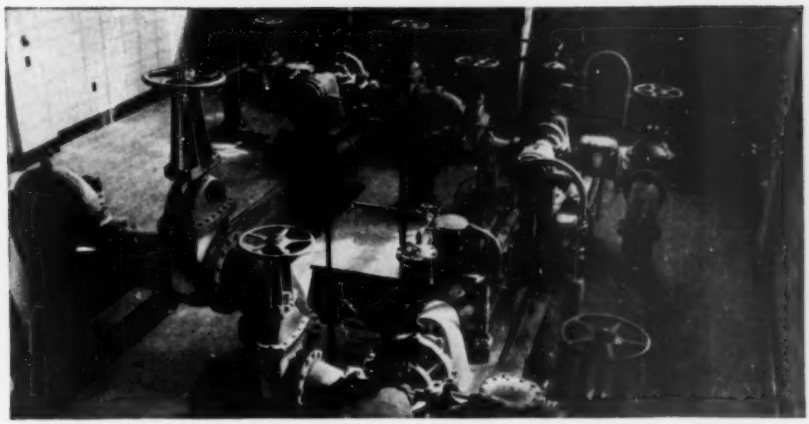

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The illustration shows the pump room, entirely equipped with Rensselaer gate and check valves. All gate valves 4 inch and larger in the entire plant are also Rensselaer.

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COSTS ARE REDUCED WHEN *LEADITE* IS USED

Of course, the greatest advantage in using LEADITE, is, that it makes a good, tight joint,—and thus reduces leakage to a minimum,—but LEADITE also offers the following advantages, which are worthy of serious consideration: Saves caulking expenses—Reduces cost of digging large bell-holes —Saves in cost of material—Reduces time required for pumping "wet trenches"—Saves time in preparation—Saves time in handling on the job—Saves in freight and hauling charges.

Another point, LEADITE saves "interest charges" by speeding up the completion of the water line.

The true value of LEADITE is best indicated by the fact that it has been used on THOUSANDS OF MILES of Water Mains,—all over this Country, as well as in many Overseas Countries.

The Pioneer self-caulking material for c. i. pipe,
Tested and used for over 40 years,
Saves at least 75%.

THE LEADITE COMPANY

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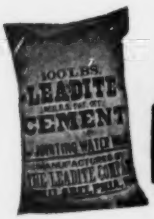

No Caulking